WATER REUSE AND ENVIRONMENTAL CONSERVATION PROJECT

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INTEGRATED WATER RESOURCES MANAGEMENT IN INDUSTRIAL ZONES

AQABA WATER REUSE MASTER PLAN

APRIL 2012

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Submitted to:

USAID Jordan

Prepared by:

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LIST OF ACRONYMS

ADC	Aqaba Development Corporation
AIIE	Aqaba International Industrial Estate
AM	Aqaba Municipality
ARW	Agricultural Reclaimed Water
ASYCUDA	Automated System for Customs Data
ASEZ	Aqaba Special Economic Zone
ASEZA	Aqaba Special Economic Zone Authority
ADC	Aqaba Development Corporation
ARA	Aqaba Regional Authority
AWC	Aqaba Water Company
EIA	Environmental Impact Assessment
EPA	Environmental Protection Agency
GIS	Geographic Information System
HPC	Heterotrophic Plate Count
IWRM	Integrated Water Resources Management
JPMC	Jordanian Phosphate Mining Company
JS	Jordanian Standard
JVA	Jordan Valley Authority
KHIA	King Hussein International Airport
L/S	Liters per Second
MCM	Million Cubic Meters
MWI	Ministry of Water and Irrigation
NRW	Non Revenue Water
PW	Potable Water
SIZ	Southern Industrial Zone
RIAL	Reuse for Industry, Agriculture, and Landscaping
URW	Urban Reclaimed Water
USAID	United States Agency for International Development
USEPA	United States Environmental Protection Agency
WAJ	Water Authority of Jordan
WMO	World Meteorological Organization
WREU	Water Reuse and Environment Unit
WRMD	Water Resources Management Directorate
WWTP	Wastewater Treatment Plant

AQABA WATER REUSE MASTER PLAN

1.0 SUMMARY

The US Agency for International Development (USAID) Water Reuse and Environmental Conservation Project is tasked (under Task 2.3) with preparing a water reuse master plan for the Aqaba Industrial Zone. IWRM Plans are required for two existing industrial zone sites in Jordan. The first site is the Aqaba Special Economic Zone, and the second site is yet to be determined. The Aqaba Water Reuse Master Plan will include:

- Review and summary of existing water sources, current and projected needs of water use (domestic, industrial, agricultural etc.) until 2030.
- Review and summary of wastewater sources, quantities, and quality, wastewater treatment, and reuse of treated wastewater, under current and projected conditions (2030).
- Review and updating of the original RIAL I Aqaba water reuse allocation strategy to the level of a Water Reuse Master Plan incorporating considerations for a) treatment levels (secondary, tertiary), depending on ultimate use of the treated wastewater, b) institutional issues (e.g. needs of reuse water for different end users and purposes), c) policy issues (e.g. water reuse pricing, allocation of reuse water for different sectors etc.), d) reclaimed water distribution plan utilizing preliminary hydraulic modeling. While the Water Reuse Master Plan will address the current reclaimed water system, particular focus will be given to the development and reclaimed water needs in the southern part of Aqaba. These considerations will take into account local, regional, and national perspectives in Jordan.
- The Water Reuse Master Plan will include description of activities performed, findings and recommendations,
- Presentation of the Water Reuse Master Plan to stakeholders in a workshop.

This report provides detailed information regarding the composition and capacities of Aqaba’s water resources, including potable, wastewater, and reclaimed water infrastructures.

Water demand projections are presented along with analyses, evaluations and recommendations on how to meet these demands. Planning for growth will enable structured growth to occur in a cost effective and efficient manner.

Drinking water demand is expected to exceed the available supply within five years. Immediate steps should be taken to establish a supplemental, desalinated water supply in south Aqaba. As a conservation strategy, the practice of using potable water for landscape irrigation should be discouraged. Additional quantities of reclaimed water can be made available for landscape irrigation by increasing the capacity of the mechanical wastewater treatment plant and reducing flows into the natural plant.

Several major developments that have suspended construction in the last three years are likely to move forward as the economic health of Jordan improves. In preparing this master plan, Aqaba's reclaimed water infrastructure was modeled and evaluated for the increased demands that are anticipated in the near term. The model showed that the present network of piping will need reinforcement and expansion to deliver reclaimed water to new developments.

Aqaba should move toward full water cost recovery by establishing a potable water tariff in the economic sectors anticipated to grow the fastest: touristic and commercial. The increased cost differential between using potable and reclaimed water for landscape irrigation will justify private investment in reclaimed water distribution infrastructure.

2.0 INTRODUCTION

2.1 Purpose, Objective, and Limits of Study

This Water Reuse Master Plan is intended to address the comprehensive multi-use water needs in the Aqaba region. The plan evaluates the use of reclaimed water (that is, treated wastewater) for industrial, agricultural, and landscape irrigation purposes.

The study area is limited to the boundaries of the Aqaba Special Economic Zone, an area of 375 km^2. The zone is bounded to the west by the Jordanian coastline and the Israeli border, and to the south by Saudi Arabia; it includes the seaports of Jordan, an international airport, and the city of Aqaba.

Currently, the reclaimed water generated from the wastewater treatment plant in north Aqaba is used to meet the needs of these three applications (industrial, agricultural, and landscape irrigation). With the continued growth of residential, commercial, agricultural and industrial developments, Aqaba is faced with the challenge of managing the significantly increased volume of wastewater generated, particularly from developments in South Aqaba and other locations such as the Ayla, Saraya, Marsa Zayed developments, and of addressing the need for reclaimed water use.

Several studies have been conducted to address the management of current and future wastewater generation and treatment. However, these studies have not fully evaluated the reclaimed water system.

This plan will evaluate the reclaimed water system for current and projected conditions of growth and development in Aqaba. This evaluation will consider the existing reclaimed water system's capacity and the impact of the demands for reclaimed water use from the projected growth and development in Aqaba, particularly from the multiple new developments.

Recommendations will be made regarding upgrades and modifications necessary to the existing reclaimed water system, including consideration of levels of treatment in the existing north Wastewater Treatment Plant (WWTP), and a proposed new treatment plant in south Aqaba. The integrated plan considering wastewater generation and treatment and the reclaimed water system will facilitate the regulators in their decision-making to meet the future growth and development needs of Aqaba.

2.2 Description of the Study Area

The City of Aqaba is situated at the head of the Gulf of Aqaba, 330 km south of Amman (see Figure 2-1). The Gulf of Aqaba is a deep narrow body of water, bordered by Israel, Jordan, Egypt and Saudi Arabia, and is one of the hinges connecting the Asian and African continents. Aqaba is the largest city on the Gulf of Aqaba, with a 27-km coastline.

The city is connected to the rest of Jordan by the Desert Highway and the King's Highway. It is connected to Eilat, Israel by the Al Mabar crossing and to Haql, Saudi Arabia by the Durra Border Crossing. The Arab Bridge Maritime company vessels connect Aqaba to the Egyptian ports of Taba and Nuweiba. Aqaba also contains an International Airport, which is located to the north, giving it unparalleled transport links to the Middle East, Africa and Europe.

Aqaba is being primed as one of Jordan's primary industrial centers; several key heavy industries are planned for the south and the desert northeast of the city, and light manufacturing, assembly and processing plants are planned for the northwest section, near King Hussein International Airport.

Aqaba City is located within the Aqaba Special Economic Zone (ASEZ), which was introduced in 2001. The ASEZ was set up by the government of Jordan as a liberalized, low taxed, duty-free and multi sector development zone, principally to encourage multiple investment opportunities. The formation of the ASEZ area has assisted in producing the high level of growth now being seen in Aqaba, one of the highest growth rates in Jordan. The zone covers approximately 375 km^2 and includes the land borders of Israel and Saudi Arabia extending to the territorial waters of Egypt. The zone, which incorporates the City of Aqaba with a population of approximately 100,000 people, has all the physical and social infrastructure and utilities to serve as a flourishing city.

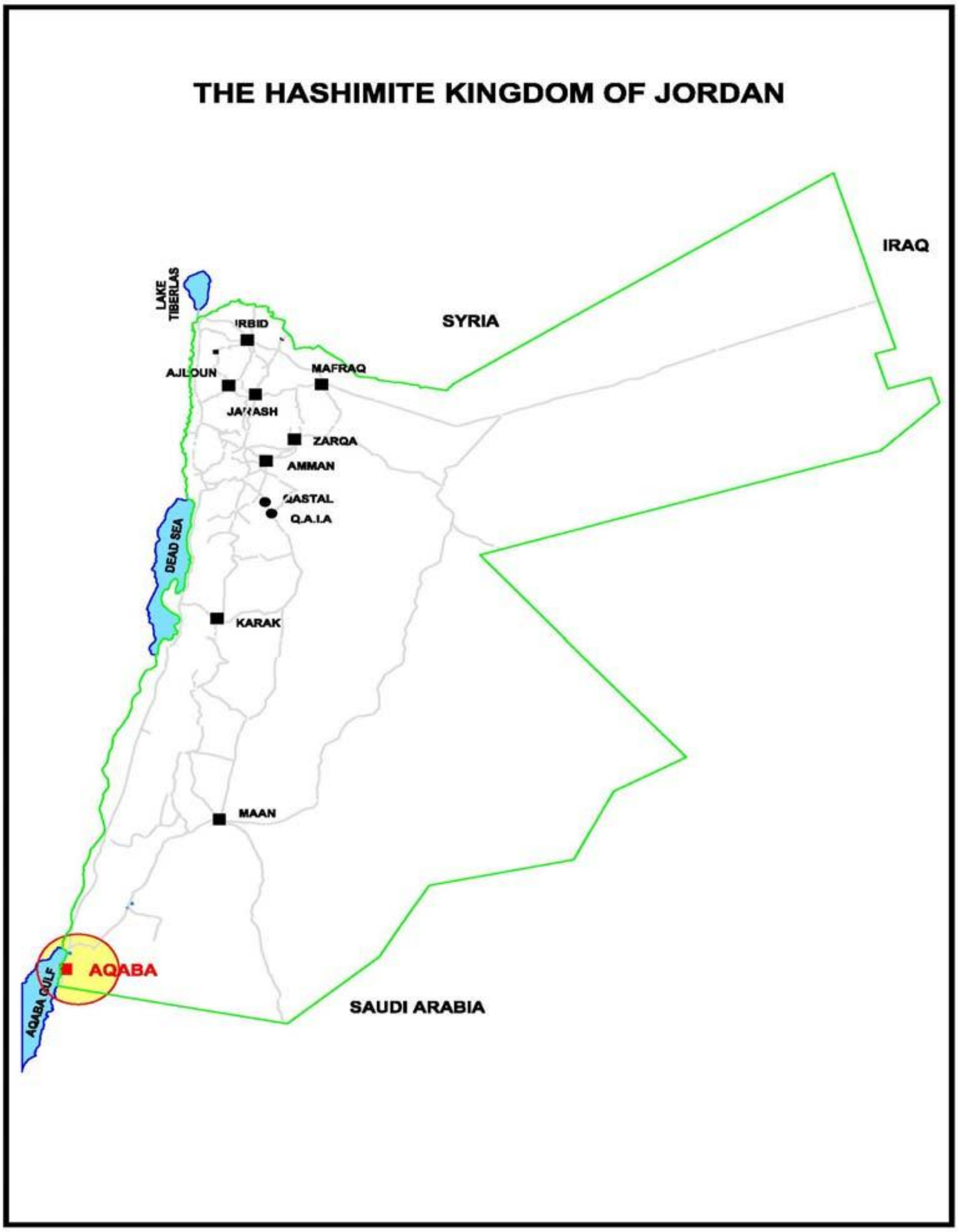

Figure 2-1 – General Location of Aqaba

Benefiting from its location and status as Jordan's special economic zone, Aqaba's economy is based on the tourism and port industry sectors. The economic growth in Aqaba is higher than the average economic growth in the country. Under the special economic zone status, some investments and trades are exempted from taxation. As a result, new resorts, housing developments, and retail outlets are being constructed. New projects such as Tala Bay and Saraya al Aqaba will provide high-end vacation and residential homes to locals and foreigners alike. The study area with locations of its major developments is presented in Figure 2-2.

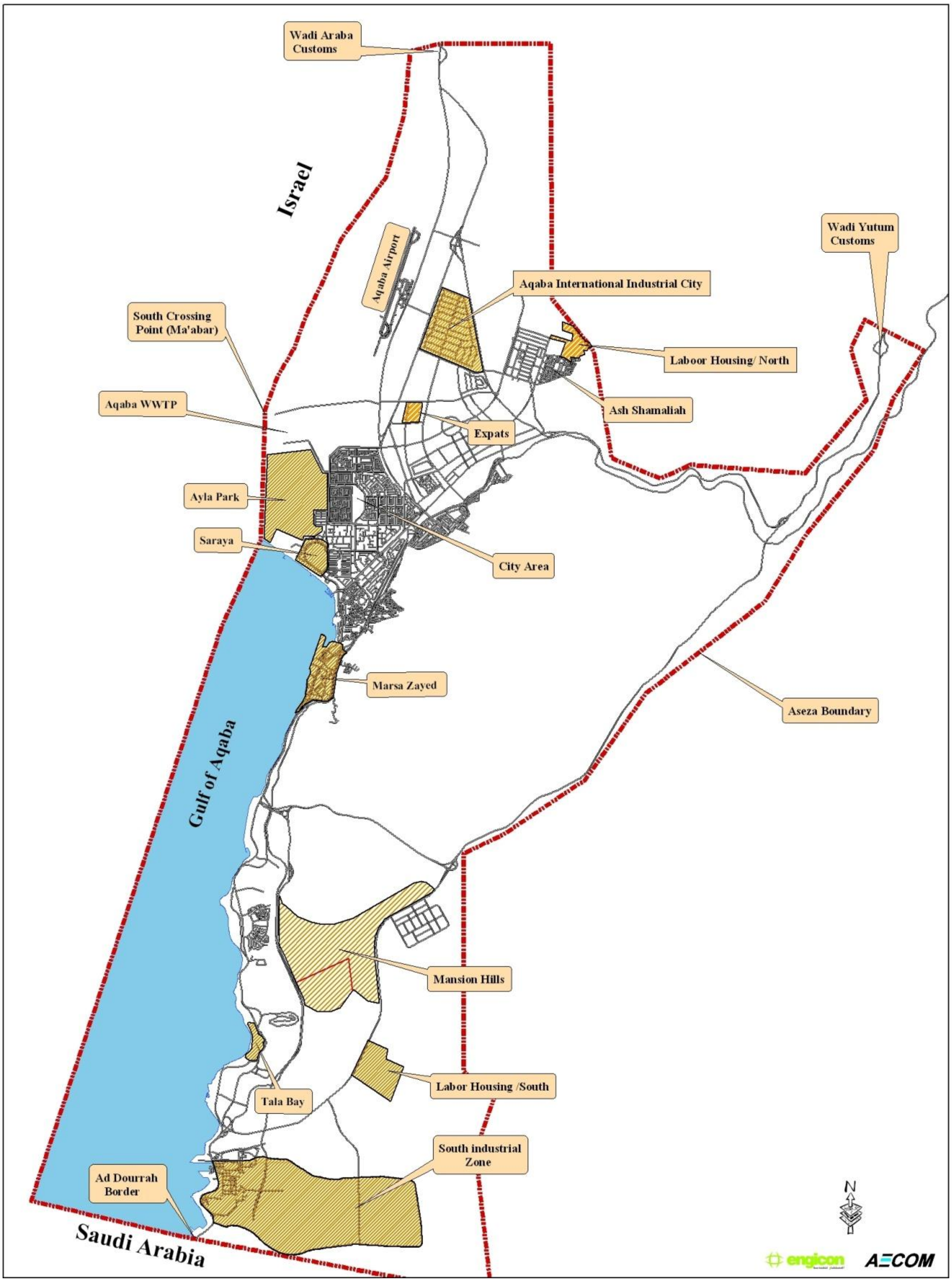

Figure 2-2 – Major Developments in Aqaba

Aqaba acquires its importance from being Jordan's only port and from its historical role as a vital crossroad connecting trade routes in the Middle East, Africa, and Europe.

Recent fast investment and development suggests that Aqaba is regaining its historical role as a center for trade, industry, and cultural exchange within the region. These rapid changes present serious challenges to the existing infrastructure and its adequacy to accommodate the newly generated loads. The wastewater collection system is seen as one of the most important service sectors; hence the need to update the existing Master Plan.

2.3 Summary of Previous Reports and Studies

Within the past five years, several planning documents have addressed water supply, wastewater collection and treatment, and developments in this study area. The project team has reviewed these documents, and while their predictions for economic growth in Aqaba have proven to have been somewhat optimistic, the detailed infrastructure information presented is comprehensive and relevant to this study. Following are summaries of these plans and reports.

Aqaba Wastewater Collection System Master Plan by MWH, July 2010 (MWH 2010)

The Wastewater Collection System Master Plan was undertaken for the city of Aqaba as an update to an earlier master plan completed in 2000.

The Aqaba wastewater collection network covers approximately 80 km^2 and serves a mixture of residential, commercial, light industrial and regal developments. The Aqaba WMMP presents a proposed expansion strategy for upgrading to meet the catchment growth predicted to the design year 2030.

Based on analysis of the existing system at that time, the study concluded that the overall collection system is in good condition to cope with the increased flows predicted in the year 2030, while the existing WWTP will become overloaded by 2020, mostly due to the completion of significant new developments such as Ayla, Saraya and Marsa Zayed. The recommendations presented can be summarized as follows:

- Expansion of Aqaba WWTP
- Construction of a new pumping station and rising main to serve the airport
- Replacement of Main pumping station and its associated rising main
- Construction of new sewers to serve the currently vacant areas allocated for development on the outskirts of Aqaba

Aqaba Master Plan Report by Engicon, September 2009 (Engicon 2009)

This 2009 report presents a master plan for the water supply system for Aqaba city, including the South Coast with its new touristic projects, industrial zones, and ports.

Capital improvement projects for the year 2030 were proposed in this study, including reinforcing or replacing some of the system components.

Based on the population and water demand projections calculated in the study, the study concluded that the total demand of Aqaba city will exceed the water supply of the Qa Disi (Disi) aquifer. As a result, the study recommended the following:

- Dedicate the 17.5 MCM allocated from Disi to supply Aqaba city

- Use the desalination plant to provide the South Coast and deliver the surplus to Aqaba city
- Improve Aqaba city water network to meet the 2015 and 2030 projected demands

Interim Design Report of the South Coast Wastewater Treatment Plant by SIGMA, August 2008 (Sigma 2008)

The 2008 Report presents a draft detailed design of a new wastewater treatment plant, pumping stations and majority of wastewater networks to serve the South Coast by the year 2030.

A financial analysis and cost estimate for proposed WWTP and pumping station are also presented in the report.

The proposed treatment plant was designed to receive the flow at two stages:

- Stage 1 with average daily flow of 5,000 m^3/day
- Stage 2 with average daily flow of 15,000 m^3/day

The existing and under construction projects were given the priority to be served by a network and a treatment plant.

South Zone Master Plan by Royal Haskoning, April 2006 (Haskoning 2006)

This 2006 report provides an overview of the master plan for the South Zone in Aqaba. The plan comprises a physical plan for the phased development of both port and industrial zone within the South Zone for the period 2006-2030, stating that expansion of the industrial zone has been planned without knowledge of any firm customer demands for 80 % of the industrial land available in the South Zone.

The report contains a description of the existing physical environment, including existing infrastructure and utilities, port, and industrial installations within the South Zone. It also describes the strategy for development of the plan, based on the identified and new industries that may develop in the industrial zone. The report presents a summary of the South Zone Master plan together with the required supporting infrastructure. The report concludes with a discussion on plan implementation with regard to phasing and costs.

King Hussein International Airport Master Plan by CHANGI, August 2008 (Changi 2008)

This master plan report provides guidance for future development of King Hussein International Airport (KHIA). It also sets out the land use strategy to enable the airport to attract and accommodate investments in various aviation related businesses.

Based on the annual number of passengers handled at KHIA between 1990 and 2007, passenger forecasts were projected by this study for the years between 2008 and 2028, assuming a relatively peaceful environment in the Middle East during the forecast period. Utilities including water and wastewater were discussed in this report.

The proposed developments will prepare the airport to adequately meet the future traffic demand throughout the 20-year planning horizon from 2008 to 2028. Implementation was suggested to be carried out in three phases as follows:

- Phase 1 Development (2008-2013) - To meet the traffic demand in 2018
- Phase 2 Development (2014-2018) - To meet the traffic demand in 2023
- Phase 3 Development (2019-2023) - To meet the traffic demand in 2028

Master Plan for North and South Villages by ICON, May 2007 (ICON 2007)

The report presents a master plan for the North and South Villages in Aqaba, which will comprise permanent and temporary labor housing to support the anticipated growth of Aqaba associated with expanded industry, tourism, and port relocation. The total area of 189 hectares will ultimately house 50,000 people during assumed 3 phases of the project: phase 1 (up to 2010), phase 2 (complete 2012-2015), and phase 3 (up to 2020).

The study estimated the demand for water and wastewater treatment based upon projected population estimates. Supplemental analysis of water and sewer requirements for each village, as well as connections to existing infrastructure, is provided in an appendix to the report.

All infrastructure recommendations of this study have been sized to meet 2020 demands.

The study suggests that access to the area will be provided and major utility hookups will be provided during phase 1, including water and sewer connections.

The study mentioned that a new sewer system with wastewater treatment plant will be constructed in 2010 to serve the southern region of Aqaba. The south village was proposed to be connected to the new sewer system through a sewer line of 5km. In case of delay of the 2010 treatment plan project, a chemical compacted unit was proposed as an interim solution.

Master Plan for Upper Town Project in Aqaba by Engicon (Engicon 2008)

The report presents a master plan for the plot designated for the Expat Residential Area and related preliminary Infrastructure design, based on the guidelines provided by ADC.

The study evaluates the site based on many aspects and considers existing infrastructure such as potable water supply and sewer system.

The general plan of this report was divided into active development zones, including Aqaba Town, Port areas, Coral Coast, Southern Industrial Zone and Airport Industrial Zone. The plot allocated for the Expats Residential area is within the Aqaba Town development zone.
The report mentioned several nearby developments that are proposed, planned, or under construction, including Arab Group for International Investments (Al-Qasaba Gated Compound), Corporate Zone, American School, Al-Karamah Residential Area, Dormitories and academy/airport related sectors, and Aqaba Industrial City.

2.4 Stakeholder Responsibility and Involvement

Several organizations have various levels of responsibility for the management of water resources in Aqaba. At the national level, the Ministry of Water and Irrigation (MWI) is responsible for the monitoring of Jordan's water sector, water supplies, wastewater systems, and related projects, and for the planning, management and formulation of national water strategies and policies. As part of the MWI, the Water Authority of Jordan (WAJ) has responsibility for all of the water and sewerage systems. Another arm of the MWI, the Jordan Valley Authority (JVA), is responsible for the economic development (together with water development and distribution) of the Jordan Rift Valley, including Aqaba. Within the Governorate of Aqaba, several local entities have been delegated authority to act on behalf its water resources. These organizations are summarized below.

2.4.1 Aqaba Special Economic Zone Authority

The Aqaba Special Economic Zone (ASEZ) defines its role as follows (www.aqabazone.com):

> The Aqaba Special Economic Zone (ASEZ) was launched in 2001 as a duty-free, low tax multi-sector development zone. It encompasses an area of 375 km^2, including the coastline (27 km), seaports, international airport, and the city of Aqaba with a current population of over 100,000 people.

The zone offers global investment opportunities including (USAID RIAL 2005):

- Tourism
- Recreational services
- Professional services
- Multi-modal logistics
- Value-added industries
- Light manufacturing.

ASEZ is regulated by the Aqaba Special Economic Zone Authority (ASEZA), which has been mandated with the authority to manage, regulate and be the municipality for the ASEZ.

ASEZA is charged with creating and preserving Aqaba as a competitive international investment location. ASEZA maintains a streamlined investment environment and encourages private sector participation in all aspects of the Zone's development and operations. It is administered and supervised by a Board of Commissioners and assigned the following functions according to Law Number 32 for the year 2000, Article 9 (www.aqabazone.com):

A. Develop and qualify the Zone to attract investments and create an advanced investment environment to stimulate industry, trade, tourism and services in the Zone

B. Increase job opportunities for Jordanians, coordinate and cooperate with investors in the Zone to train, qualify and enhance the capacity of Jordanian manpower and give the priority to their employment

C. Enhance the role of the private sector in participating in the development of the Zone, including providing infrastructure services and any public services

D. Encourage competition and prevent monopoly in the various economic activities within the Zone

E. Plan, design and execute projects for the development of the Zone in various fields, directly or through other parties

F. Protect the environment in the Zone

G. Encourage Registered Enterprises to conduct and support research and development

Also, the Authority has the responsibilities and authorities in relation to the following, according to Article 10 of the Law Number 32 (www.aqabazone.com):

1. Regulate and control the economic activities to assure conformance with ASEZA Law No. 32/2000 and the regulations issued pursuant to it, including public health and safety
2. Issuing permits and certificates and any other authorizations which pertain to conducting economic activities in the Zone according to the provisions of ASEZA's Law and the Regulations

3. Zoning of cities, villages and buildings

4. Municipal affairs

5. Protecting the environment, water resources, natural resources and biological diversity

6. Control the imported or exported food and drugs to or from the Zone and control and inspect all places designated for slaughter, food preparation and manufacturing and its derivatives, selling and serving

7. Customs procedures and matters

8. Collecting taxes, fees, fines and service charges stipulated in ASEZA's Law and the Regulations

9. Work and employees affairs

10. Any authorities entrusted to other official bodies accorded to the Authority by the Council of Ministers

2.4.2 Aqaba Water Company

The Aqaba Water Company (AWC) defines its role as follows (http://aqabawater.com):

> The establishment of Aqaba Water Company (AWC) came as a result of implementing His Majesty King Abdullah II's vision of dealing with the water issues in the Kingdom as a strategic challenge that requires balancing the needs of industry and agriculture, and considering drinking water as essential and most important in view of the limited water resources. The newly established company started its operations in 2004 as a legal successor to the WAJ in the Aqaba Governorate.

It is the first company of its kind in the Kingdom entrusted with managing the water supply and wastewater services within its own zone of operations, and the first of its kind that enjoys financial and management independence.

WAJ has exclusive authority to develop and manage water-related services outside ASEZ, while AWC is responsible for managing the water-related services within the ASEZ.

The establishment of Aqaba Water Company came with the aim of improving the operational efficiency of the water and wastewater sectors in the Aqaba Special Economic Zone in particular and the Aqaba Governorate in general to meet the increasing demand on water and wastewater services and to improve these services provided to customers in terms of speed and quality. This is reflected positively on local residents and all investment sectors in general, such as the touristic, industrial, commercial, and agricultural sectors.

The Aqaba Water Company is assigned to perform the following functions:

- Providing water

- Acquiring water sources. To achieve the quantity and quality of water to meet consumer needs in the ASEZ and the Aqaba Governorate, in a timely, organized, reliable, transparent and economically feasible manner to enable water to be obtained with speed and ease.

- Storage and distribution of water sources. To own, design, develop, maintain, operate and manage assets and infrastructure in accordance with the best standards and international practices to extract, store, maintain, protect, pump and distribute water in an effective, professional manner as well as to distribute water in sufficient quantity and quality to meet consumer needs in the ASEZ and the Aqaba Governorate.

- Water Handling. To sell, rent and deliver as well as to handle water in the Special Economic Zone and the Aqaba Governorate.

- Provision of wastewater services

- Treatment of wastewater. To own, design, develop, build, maintain, operate and manage assets and infrastructure in accordance with the best standards and international practices to collect, store, treat, purify, pump, recycle, extract, transport, dispose of and deal with wastewater in an effective and useful manner as well as to deal with the wastewater produced by consumers in the area and in the Aqaba Governorate, including any processed water and any resulting residues in timely, organized, reliable, transparent and economically feasible manner.

- Handling wastewater. To impose fees or any other alternative to handle wastewater. The Company has the right to sell, rent and deliver as well as to handle processed wastewater.

- Promotion of practices pertaining to water and wastewater. To promote effective and useful utilization of water resources and to handle wastewater and the use of reclaimed wastewater by consumers in the Zone and the Aqaba Governorate, through methods that may include general awareness and guidance and suitable tariff mechanisms as permitted by implementing the law and contracts.

Aqaba Water Company works to take part in the elevation of the health and environment standard and the improvement of the investment environment of ASEZ by anticipating future needs, implementing needed projects to meet the increasing demand on their services, providing pure water and effective treatment systems, and striving to affect change and technical and administrative development to reach international standards in the water industry sector.

2.4.3 Aqaba Development Corporation

The Aqaba Development Corporation (ADC) defines its role as follows (www.adc.jo):

Aqaba Development Corporation (ADC) was created in 2004 with the objective of unlocking the potential of the Aqaba Special Economic Zone by accelerating its economic growth and development.

Launched by ASEZA and the Government of Jordan, ADC owns Aqaba's seaport, airport and strategic parcels of land as well as the development and management rights for these assets in addition to key infrastructure and utilities.

ADC is mandated to develop ASEZ through building new or expanding existing infrastructure and the required superstructure, creating business enablers for ASEZ, and managing or operating its key facilities. ADC also has the responsibility to implement the ASEZ Master Plan in a manner that ensures integrated development and transforms Aqaba into a leading business and leisure hub on the Red Sea.

ADC is a private shareholding company governed by a board of directors currently wholly owned by the Government of Jordan and ASEZA, each with a 50% equity holding. ADC is operated as a private sector organization and has secured a multi-national private sector team to operate it, supported by a consortium of multi-disciplinary firms.

Utilizing partnerships with qualified private sector investors; ADC launched a number of touristic, residential, commercial and real-estate development projects. As a result, Aqaba's real estate market is witnessing growth while creating a competitive property market and business opportunities. Major investments in this sector include:

- Saraya Aqaba
- Ayla Oasis
- Marsa Zayed
- Tala Bay
- Mada'en Aqaba Real Estate Development Company
- Jordanian Engineering Association Residential Compound

- Red Sea Resort
- Tala Hills (AL HIDAB)

Industry is a key part of Aqaba's development process, and for that reason the Zone's master plan allocated different sites for the establishment of industrial projects in the Zone. The heavy industries are designated in the Southern industrial zone where electric power and proximity to ports are very important. Light to medium industries have two main allocations - near the back road around the southern area in close proximity to the zone's container terminal, and in the northern part of the city in the Aqaba International Industrial Estate with direct access to the air cargo terminal at King Hussein International Airport.

2.4.4 Aqaba International Industrial Estate

The Aqaba International Industrial Estate (AIIE) is located within the Aqaba Special Economic Zone (PA Consulting 2004). Covering 2.8 million square meters on a site 700 meters east of the Aqaba International Airport, the AIIE is strategically positioned near Jordan's borders with Israel, Egypt and Saudi Arabia. Phased development including first phase of 5,610 SQM was fully financed by a United States Agency for International Development (USAID) grant.

The AIIE defines its role as follows (www.pbiaqaba-jo.com):

Industries locating in the AIIE may invest in a wide variety of activities, including:

- Metals and Engineering Industries
- Hi-Tech
- Logistics and warehousing
- Construction material
- Plastic raw materials and finished products
- Paper-based packaging and printing
- Food processing
- Garments and fashion
- Commercial services

According to the ASEZ Law, AIIE registered enterprises will be subject only to a flat 5% income tax on profits, and will enjoy duty-free imports including capital Equipment, raw materials and other consumables. Customs clearance computerized with the Automated System for Customs Data (ASYCUDA) system.

AIIE provides support and assistance to investors before and after commencement of operation in company registration, environmental approvals, building and operating permits, civil defense approvals, customs, employment and advice on local partnering. Moreover, it offers fully serviced land for manufacturing, logistics, storage and related activities.

2.5 Description of Regulatory Framework for Water Resources Management in Aqaba

Information in the following section explains the regulatory framework for water resources management in Aqaba (USAID RIAL 2005).

2.5.1 Regulatory Role of ASEZA

The Aqaba Special Economic Zone Authority has responsibilities towards the water sector and water resources management in the ASEZ. ASEZA's role with respect to water resources management in Aqaba is defined by several strategic documents which both explicitly and implicitly define the duties of the Authority. The key documents defining ASEZA's role are briefly described below in Table 2-1 (USAID RIAL 2005):

Table 2-1: Key documents defining ASEZA's strategy, roles and responsibilities for water resources management

Document	Description
Aqaba Special Economic Zone Authority Law (August 2001)	Legal basis for establishing ASEZA as the replacement to Aqaba Regional Authority (ARA) and Aqaba Municipality (AM) as a statutory institution empowered with regulatory, administrative, fiscal and economic responsibilities within ASEZ. This law consists of many clauses specifying and regulating the different roles and responsibilities of ASEZA
Agreement to exploit all treated water from Aqaba WWTP between ASEZA and WAJ (December 2001)	Agreement to increase the sources of the water for greening at ASEZ through allocation of treated wastewater for this purpose. It specifies the roles of ASEZA and AWC in wastewater collection, storage, treatment, pumping, distribution, costing and monitoring
AWC formation agreement between ASEZA, Ministry of Water & Irrigation and WAJ (January 2004)	Signed pursuant to article No.17 of the AZEZ law and article No. 28 of the WAJ law to establish a limited liability company to develop and manage water and wastewater services in the ASEZ on such terms and conditions to be agreed in the article of association and memorandum of association
Development Agreement between ASEZA and AWC (June 2004)	Specifies the roles, authorities and obligations of ASEZA and AWC in handling water, wastewater and support services inside and outside ASEZ
Environment Protection Regulation in Aqaba Special Economic Zone (February 2001)	Deals with the requirements for EIA, air protection, marine environment protection and it stipulates the penalties for damaging the environment
Assignment Agreement between WAJ and AWC (June 2004)	The relationship between the Company and the Water Authority is regulated by an Assignment Agreement, through which the Authority's assets were transferred to the Company on 1st August, 2004.

Other relevant documents which are applicable for water resources management in Aqaba include (USAID RIAL 2005):

- Environment Protection Law January 2003).
- Water Authority Law (1988)
- Groundwater Monitoring Regulations (August 2002)
- Gulf of Aqaba Environmental Action Plan (2002).

Within ASEZA, the Commission for Environment Affairs and Health Control has overall responsibility for assessing whether or not environmental clearance is granted to all economic activities (existing and new) within the Zone, and carries out monitoring, inspection, and auditing of related activities in order to assess compliance with the stipulated environmental rules and regulations. It has three main directorates: Environmental Planning, Laboratory and Health Control. Water resources management is organized under the Environmental Planning Directorate.

The Water Resources Management Division of ASEZA has two primary functions: 1) regulation of the Aqaba Water Company, and 2) general water resources management. The regulatory activities in which the Water Resources Division of ASEZA is engaged include:

- Periodic monitoring of water and wastewater quality.
- Surveys of customer satisfaction.
- Monitoring and inspection of water and wastewater system performance.
- Review of AWC financial performance.
- Review of utility development plans

In addition to the role of utility regulator, ASEZA provides general stewardship over water resources in Aqaba. With an overall responsibility for environmental protection, ASEZA will be charged with ensuring that the quality and availability of water resources in ASEZ will be maintained (or improved). General water resources management activities in which the Water Resources Division of ASEZA is engaged include:

- Approval and permitting of water system infrastructure
- Monitoring of water quality (groundwater and surface water)
- Providing technical input to water resources management planning as required
- Reviewing ASEZ development with respect to water (EIAs, development permits, etc.)
- Performing outreach and raising awareness regarding water resources issues in ASEZ
- Developing and maintaining comprehensive database of water information.

(USAID RIAL 2005)

2.5.2 Regulatory Role of AWC

The USAID technical report for Procurement Project Management (USAID 2004) defines the AWC regulatory role as follows:

> An initial Memorandum of Understanding with the Ministry of Water and Irrigation, the Water Authority of Jordan, and the ASEZA set out the fundamental provisions related to the establishment of AWC including a commitment that AWC would operate as a financially viable, self-sustaining entity run under commercial principles. It was also agreed that AWC would support the competitive advantage of the Special Economic Zone by providing high-quality, efficient water and wastewater services; improved access for new customers; and cost-competitive pricing. Further, Aqaba water assets were transferred to AWC and the Ministry/WAJ provided initial working capital of JD 0.5 million.
>
> The company's capital is estimated at JD 60 million, including its ongoing and future planned projects. Furthermore, both ASEZA and WAJ will monitor AWC's overall performance until a national water monitoring unit is in place.

The company is regulated by a transitional structure that later will be substituted by a national regulatory agency. The initial regulatory arrangement consists of a shared responsibility between WAJ and ASEZA where WAJ will regulate the supply side through an Assignment Agreement and ASEZA will regulate the consumer side through a Development Agreement. The two agreements include issues representing the interest of each party regarding the transfer of assets and rights, introducing clauses on regulatory matters, establishing performance indicators and standards of quality of service and addressing specific issues such as bulk water supply and tariff setting.

AWC had to follow a unique legal and institutional framework. Three main laws set the framework for the company: the Companies Law, the WAJ Law and the ASEZA Law. The requirements of every law put into a single transaction dictated the sequence of the process which is presented graphically in Figure 2-1:

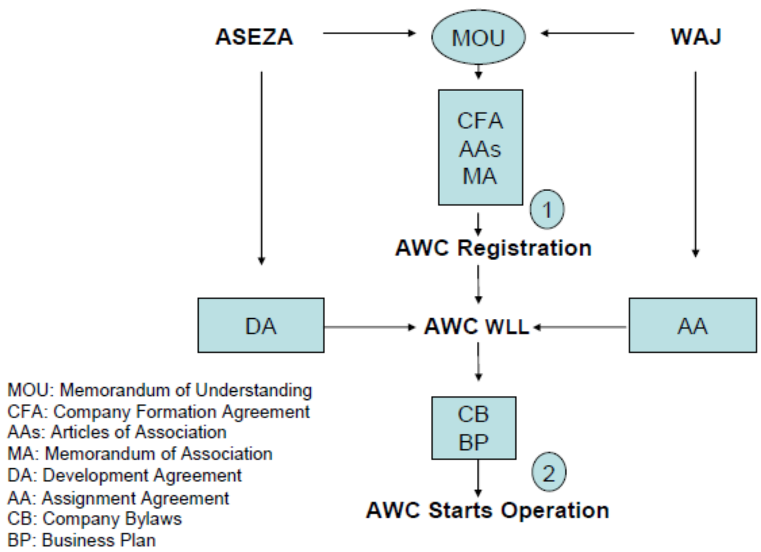

Figure 2-1: Legal and Institutional Framework (Source: USAID 2004)

The Memorandum of Understanding was the initial step in the process which was followed by the registration of AWC with the Company Formation Agreement, the articles and the memorandum of Association. The creation of the company was the first part of the process and allowed the company to subscribe the next documents that would allow the company starts its operations.

After completing the Assignment and Development agreements, the parties: AWC, MWI/WAJ and ASEZA finalized the process and signed the final agreements to start operations. Additional documentation was needed to start operations such as the business plan and certain company bylaws. Moreover, AWC has developed regulations at each and every level to make all employees and members of the company accountable to its level of responsibility as individuals as well as a group of individuals. At the top and outside the company responsibilities are the regulatory framework defined in the Assignment and Development agreements, inside the company the bylaws defines the Management Committee functions (Board of Directors), the Customer Service responsibilities, the Finance and Accounting processes, the Standard

Operations functions, the Purchasing and Procurement procedures and the Human Resources regulations.

On the bulk water supply side, underground water resources remain under the ownership of the Government of Jordan. Wells supplying AWC as well as land adjacent to the wells are included as transferred assets.

The extraction of water is limited to a maximum of 17.5 MCM/year of Disi Water and in non-normal withdrawal conditions, the limit can be increased up to 20 MCM/year for a maximum period of 2 years. AWC will be allowed to develop new wells procuring the respected permits from ASEZA and WAJ.
Although AWC will charge only rates contained in a Tariff Schedule approved by the Council of Ministers, it has the right to submit a proposed Tariff Schedule or change to ASEZA and WAJ or to the national regulator in the future.

The tariff structure is defined in the Development Agreement based on an Allowed Revenue formula that includes the cost of purchased bulk water, cost of purchased desalinated water, operating expenses including maintenance costs, taxes, depreciation of assets and a return on net equity of not more than 10 %.

AWC can propose a new structure of classes of customers, and the allocation of costs between user groups. Every proposed structure should be based on cost recovery and permitted return on equity.

3.0 ASSESSMENT OF STUDY AREA

3.1 Demographics

The population of Aqaba has increased significantly during the last years, a trend that is expected to continue for the foreseeable future. Total population within the ASEZ area was estimated at 104,400, from which 96,345 are served by Aqaba wastewater system catchment area (MWH 2010).

As detailed in the wastewater master plan prepared by MWHAJ in 2010, the population catchment area is projected to increase 153,000 and 233,000 in the years 2020 and 2030, respectively, using a 4.3 % annual growth rate.

3.2 Economic Development Plans

Currently, there is a considerable number of new developments in Aqaba at different stages of planning and development. Those developments will be connected to the water supply and wastewater collection systems.

Discussed below are the largest developments, which have been in various stages of implementation for many years. Due to the recent economic downturn, the progress of these developments has slowed down, and their completion may be delayed.

Saraya

The Saraya development is located on the coast between the Royal Palaces and the town. Saraya consists of a combination of residential, commercial, properties and hotels. According to the developer, this is a 1-phase project that is expected to be completed by 2014.

The completed fully occupied development is expected to have a water demand of 3,000 m^3/day, and will be connected directly with AWC wastewater collection system. The project is expected to use urban reclaimed water for landscaping purposes.

Ayla

Located in the west side of Aqaba, Ayla will include hotels, residential communities, golf course, and a town center that houses a marina, retail shops, cafes, in addition to entertainment and recreational facilities, all build around a man-made lagoon.

The completed fully occupied development is expected to have a water demand of 5,380 m^3/day. According to the developer, listed below are the completion date, water demand and wastewater generated from each phase (email, Hussein al Share of Ayla).

Table 3-1: Ayla Phasing and Projected Flows

Phase	Year	Water Demand	Wastewater Generator
1	2012-2015	1,988	1,690
2	2016-2019	1,465	1,245
3	Starts 2020	1,928	1,639

According to the developer, Ayla is designed to be connected to the existing Aqaba wastewater treatment plant taking in consideration the feasibility to be connected to a dedicated local treatment plant (Ayla WWTP) in the future .The design of the network is flexible for both connections.

Ayla has a projected demand for urban reclaimed water of 5,500 m^3/day, from which 500 will be used for landscaping, and the rest for maintaining a golf course.

Marsa Zayed

Marsa Zayed, located south of the main town center, is the largest of the new developments planned in Aqaba, and will be located on approximately 640 hectares of land that is currently occupied by the port, which will be relocated further south. This development will include offices, hotels, recreational areas, commercial areas, and residential properties.

The completed fully occupied development is expected to generate up to 16,190 m^3/day of wastewater.

In the absence of specific information from the developer, it was assumed that the development will be implemented in several phases beginning in 2015 , and 100% completed and occupied by 2030, as presented by the wastewater master plan prepared by MWH.

South Industrial Zone

ADC intends to designate the entire South Zone, independent of the seaport, as an Industrial Estate. The “Southern Industrial Zone” (SIZ) will be located on 12 km2 of vacant readily developable land, which surrounds the already existing heavily industrial district. It will also be directly adjacent to the proposed site of the new Aqaba seaport. The development concept for the SIZ is based on the concept of building an industrial area that provides for the expansion and improvement of existing industries in an orderly manner, which will facilitate the start of other new and related industries.

It is anticipated that this will zone will develop within the next four to five years.

King Hussein International Airport

Currently, there is a plan for a major expansion of the airport. The existing airport is not connected to the sewer system, and it serves approximately 240,000 passengers per year. The number of passengers is expected to increase to 1,560,000 and 1,800,000 by the years 2020 and 2030, respectively (MWH 2010).

Using an industry standard of 15 liters of wastewater generated per passenger, the total daily flow expected by the years 2020 and 2030 is 65 and 75 m^3/day, respectively.

Northern Industrial Area

The Northern Industrial Area, located to the north of Aqaba, is expected to expand significantly, but detailed information about the expansion is currently unavailable.

3.3 Current Water Costs and Rates

Water tariffs for both drinking water and wastewater services are dictated by the Water Authority of Jordan for all of the governorates. Water tariffs for reclaimed water are negotiated by AWC.
Water and sewer services in Aqaba, as in all of Jordan, are heavily subsidized. The revenue covers only part of the operation and maintenance costs. The tariff is structured as a progressive pricing system under which users pay a higher tariff per cubic meter if they consume more water.

In 2011, users were subject to their first tariff increase since 1997. To soften the impact, the WAJ has moved to monthly billing. The tariff increase of 9 % for volumes beyond the first block became effective in January 2011. The first block corresponding to a consumption of up to 6 cubic meters per month is a minimum charge independent of the amount of water consumed. In 2011, the minimum charge will be JD1.70 per month including sewer services or JD1.50 per month without sewer service. These charges include a fixed surcharge and a meter fee. Tariffs for other amounts of domestic water use appear below in Table 3-2. The column on the far right is the volume of water used in cubic meters. The second and third columns from the right are the fees charged for water + wastewater services and water service only, respectively:

Table 3-2: Aqaba Domestic Water Use Rates

مياه العقبة
Aqaba Water

تعرفة المياه السارية لشركة مياه العقبة

من ٤٢-٦١ متر مكعب			من ٢٢-٤١ متر مكعب			من ١-٢١ متر مكعب		
بدون صرف صحي	مع صرف صحي	كمية الاستهلاك	بدون صرف صحي	مع صرف صحي	كمية الاستهلاك	بدون صرف صحي	مع صرف صحي	كمية الاستهلاك
34.37	51.01	42	9.87	13.61	22	1.50	1.70	من صفر ولغاية ٦ متر مكعب
35.97	53.41	43	10.72	14.91	23			
37.57	55.81	44	11.57	16.21	24			
39.17	58.21	45	12.57	17.81	25			
40.77	60.61	46	13.57	19.41	26			
42.37	63.01	47	14.57	21.01	27	2.20	2.44	7
43.97	65.41	48	15.57	22.61	28	2.34	2.62	8
45.57	67.81	49	16.57	24.21	29	2.49	2.81	9
47.17	70.21	50	17.57	25.81	30	2.63	2.99	10
48.77	72.61	51	18.97	27.91	31	2.78	3.18	11
50.37	75.01	52	20.37	30.01	32	2.92	3.36	12
51.97	77.41	53	21.77	32.11	33	3.97	4.66	13
53.57	79.81	54	23.17	34.21	34	4.47	5.41	14
55.17	82.21	55	24.57	36.31	35	4.97	6.16	15
56.77	84.61	56	25.97	38.41	36	5.47	6.91	16
58.37	87.01	57	27.37	40.51	37	5.97	7.66	17
59.97	89.41	58	28.77	42.61	38	6.47	8.41	18
61.57	91.81	59	30.17	44.71	39	7.32	9.71	19
63.17	94.21	60	31.57	46.81	40	8.17	11.01	20
64.77	96.61	61	32.97	48.91	41	9.02	12.31	21

Source: Aqaba Water Company

Tariffs for non-residential (non-domestic) customers are set at JD 1.00 per cubic meter consumed plus JD 0.50 if connected to the sewer system, independently of the level of consumption.

Current tariffs for reclaimed water are negotiated by AWC. Customers and their rates are shown in Table 3-3:

Table 3-3: Aqaba Reclaimed Water Use Rates

Customer	Reclaimed Water Quality	Negotiated Rate	Comments
Jordanian Phosphate Mines	Urban Reclaimed Water	JD 0.70 / m^3	Potable water also negotiated at JD 0.70
ASEZA	Urban Reclaimed Water	JD 0.10 / m^3	
ASEZA	Agricultural Reclaimed Water	JD 0.03 / m^3	ASEZA also pays pumping power costs
King Hussein International Airport	Agricultural Reclaimed Water	JD 0.25 / m^3	

3.4 Land Use

ASEZA is the official entity that has authority for setting land use. ASEZA has an approved General Plan that defines land uses throughout the zone. The plan was last updated in 2005. Based on discussion with ASEZA, changes in designated land uses are implemented based on investment priorities.

3.5 Potable Water Supply System

3.5.1 Groundwater Supplies

Currently, Aqaba's potable water supply is solely is supplied from 17 wells, in Qa Disi and Abu Ad Dadaa well fields, withdrawing water from Qa Disi groundwater aquifer. This water is then conveyed to the 2,250 m^3 Collection Reservoir, and used for domestic, commercial and industrial consumption in Aqaba.

From the 17 wells, four are operational in Abu Ad Dadaa well field, nine are in the Qa Disi well field, while the remaining four wells are purchased by AWC from Rum Agricultural Company and are connected to the system.

These wells are equipped by submersible pumps delivering water to the Collection Reservoir through a 17 km of collection mains ranging in size between 250 mm and 700 mm.

The maximum annual production is limited to 17.5 MCM/year, corresponding to 555 liters/second.

According to the water system master plan, it is recommended to use the 17.5 MCM/year to supply Aqaba City, and use water from the desalination plant to supply the South Coast area, and supplement any deficiencies in Aqaba City.

3.5.2 Transmission Facilities

The 64 km transmission pipe carrying flows from the Collection Reservoir to the Terminal Reservoirs at the northern entrance of Aqaba, which runs along Wadi Yutum, is ductile iron ranging in size between 500 mm and 800 mm. There are two terminal reservoirs, named Low Terminal Reservoir and High Terminal Reservoir.

The design capacity of the transmission pipe is 663 liters/second, while it was designed to carry an average flow is 555 liters/second. Based on the 2010 water billing data provided by AWC, only 14.3 MCM was provided. Realizing that the non-revenue water account for 23 % of the water supplied, the water produced slightly tops the 18 MCM for that year.

Should a decision is made to meet Aqaba future water demands from Disi, an additional transmission pipeline will need to build to accommodate the increase in flow.

3.5.3 Potable Water Treatment Facilities

Currently, there are no treatment facilities because of the high quality of the Disi groundwater. The only treatment is chlorination that takes places at each distribution reservoir.

3.5.4 Potable Water Storage and Distribution

Water is distributed from the Terminal Reservoirs to distribution reservoirs in the city, and Wadi 2 reservoir in south coast which supplies major touristic and industrial water

users. The distribution reservoirs are called the North High Reservoir, North Low Reservoir, and Shameya Reservoir
The Low Terminal Reservoir feeds the Wadi Reservoir through 25 km of 500 mm and 600 mm ductile pipe, which is tapped along the way to feed smaller distribution reservoirs, such as the South High, South Low, Port Housing, Qabous & Yamaneyah, Jordan Fertilizers Company, and the Refinery Reservoirs.

Wadi 2 Reservoir, located on the South Coast next to the South Industrial Zone, has a 4,500 m^3 capacity.

According to the Aqaba WMP, 2009, additional reservoirs, such as the New North High and New South High reservoirs, need to be introduced in the system in order to cope with future demands.

The plan stated that deficiencies will occur throughout the distribution system under 2015 and 2030 demands, and system components has to be replaced or reinforced.

3.5.5 Currently Planned Improvements

As detailed in the plan and recently confirmed with Engicon, none of these improvements have been implemented to date. In addition to the proposed reservoirs, Engicon proposed new/upgraded pipes totaling 21 km, 12.5 km and 33.6 km for the years 2015, 2020 and 2030, respectively.

3.6 Wastewater Systems

3.6.1 Collection Service Areas

According to the Aqaba WWPM, 2010, the existing wastewater system covers an area of approximately 80 square kilometers, and serves residential, touristic, commercial, light industrial, developments. The main light industrial area(s) are located in the north adjacent to the airport.

From Aqaba’s 2009 population of approximately 104,400, it is estimated that 96,345, or approximately 92 percent, are served by the existing wastewater collection system. Worth mentioning is the considerable impact of tourists which results in temporary population increases of up to 20% during holidays and some weekends.

3.6.2 Existing System

The existing wastewater collection system that serves the City of Aqaba carries the flows to Aqaba wastewater treatment plant located northwest of Aqaba. Currently 92% of ASEZA’s population is by the system, with some scattered pockets not connected to it. Flows from those pockets are treated at a privately maintained package plant, or to a septic tank that gets empties and transported to the treatment plant using tankers.

Sewer Network

The existing sewer network in Aqaba has a total of 250 km of gravity sewers and 7 km of force mains, with pipe diameters ranging between 200 mm and 1200 mm.

Pumping Stations

There are six pumping stations currently in operation, five of which are operated by AWC, while the other is privately operated and located in the Royal Palace.
Shown in Table 3-4 below are the wastewater pumping stations operated by AWC.

Table 3-4: Wastewater Pumping Station Operated by AWC

Name	Location	Service Area
Main	Located in the Hotel area of Kornaish Street in southern Aqaba	Serves a large part of the Aqaba catchment including the catchment areas of the other pumping stations, the Old Town, Commercial area and Fourth Residential Area, which are some of the most densely populated areas of Aqaba.
Mina (PS2)	Located beside Mina Gate No.1 in the port area.	Currently only serves the area of Salah Al Deen and the port.
Hafayer No.1	Located in South Hayfayer adjacent to the Mina House Restaurant.	Al- Hafayer Area.
Hafayer No.2	Located in central Hafayer adjacent to Aqaba castle.	Al- Hafayer Area.
Hafayer No.3	Located in north Hafayer next to the Yacht Club.	Al- Hafayer Area.

3.6.3 Wastewater Treatment Facilities

Aqaba is served by one treatment plant operated by AWC and located in the north west of the catchment. The plant has two separate processes, which are a mechanical and natural treatment, with a total capacity of 21,000 m^3/day. Flows arrive to a single inlet structure which distributes the flows among the mechanical and natural plants, and each can process 12,000 m^3/day and 9,000 m^3/day respectively.

The mechanical wastewater plant employs an activated sludge treatment process (oxidation ditch) that consists of preliminary, secondary and tertiary treatment equipment. This high level of treatment allows the effluent to be reused in urban landscaping applications.

The natural wastewater plant utilizes facultative and maturation (stabilization) ponds to produce a lower quality effluent that can safely be used by farms for agricultural purposes.

In addition to Aqaba WWTP, there are several privately operated treatment plant that treat domestic wastewater, and one that treats industrial water.

A summary of the treatment plants follows in Table 3-5

Table 3-5: Wastewater Treatment Plants in Aqaba

Treatment Plant	Year Built	Type/ Served Pop	Process	Inflow (M^3/Day)	Treated Effluent (M^3/Day)	Sludge (M^3/Day)
Aqaba Mechanical	2005	Domestic 101,920	Activated Sludge Tertiary	7,500	7,000	300
Aqaba Natural	1987	Domestic 101,920	Activated Sludge Secondary	7,000	6,000	N/A
Back Road (Tala Bay)	2008	Domestic 1,000	Activated Sludge Tertiary	200	170	30
Royal Diving Club	2004	Domestic 70	Activated Sludge Tertiary	25	N/A	0.4
Central Power Plant	1986	Domestic & Industrial 385	Extended Aeration Tertiary	50 Dom 3168 Ind	Evap Ponds + Agriculture	0
JPC		Domestic				

All of the effluent from the two Aqaba wastewater treatment plants is reclaimed. It is believed that the treated effluent from the privately owned treatment plants is also reclaimed.

3.6.4 Currently Planned Improvements

As detailed in the Aqaba WWMP, 2010, a total population of 96,345 lived in the wastewater catchment area in 2009. Catchment area population is projected to increase to 153,000 and 233,000 in the years 2020 and 2030, respectively.

According to the wastewater system master plan, the total flows reaching the treatment plant averaged 16,000 m^3/day (although AWC reported accuracy problems with the plant's flowmeter), with projected flows of 62,000 m^3/day (22.6 MCM/year) and 85,000 m^3/day (31.0 MCM/year) in the years 2020 and 2030, respectively.

Based on the current rate of development deployment and the water demand projections provided by AWC, we have revised the wastewater flows for 2030 at 24.33 MCM/year and 34.18 MCM/year under the low and high projections, respectively. See Chapter 4 for details. A major development, Marsa Zayed, was assumed by the master plan to flow to the existing treatment plant. Marsa Zayed is projected to contribute approximately 5.9 MCM/year, at 85 % return rate.

Summarized in Table 3-6 are the system improvements recommended by the master plan, which include gravity sewers, force mains, pumping station, and treatment plant expansion. The proposed treatment plant expansions are based a mechanical process such that the treated effluent produced by the plant can be used for various purposes, including irrigation and industrial processes.

Table 3-6: Wastewater System Improvements Proposed by the Aqaba WWMP, 2010

Phase	Horizon	Gravity Sewers (m)	Force Mains (m)	Pumping Station	Treatment Plant Expansion
2020-1	2011-2016	28,000	0	0	Yes
2020-2	2016-2020	83,000	1,000	1	No
2030-1	2021-2025	40,000	0	0	Yes
2030-2	2026-2030	120,000	2,000	1	No

3.7 Reclaimed Water System

Currently, two types of reclaimed water are produced by Aqaba wastewater treatment plants. The Agricultural Reclaimed Water System (ARW), produced by the natural treatment (ponds), is used for irrigation of agriculture. The Urban Reclaimed Water System (URW), produced by the mechanical treatment plant, has a higher quality that is suitable for urban purposes including landscape, park, and golf course irrigation.

Description of the reclaimed water system provided below is based on Aqaba WWMP, 2010 provided by AWC and updated based on recent discussions.

3.7.1 Reclaimed Water Storage and Distribution

Agricultural Reclaimed Water

The ARW system consists of a pumping station, with high-pressure and low-pressure pumps, and a 51,000 m^3 open reservoir located near the Industrial Estate east of Aqaba International Airport.

There are three high-pressure vertical turbine pumps and two low-pressure vertical turbine pumps in the ARW pumping station. The high-pressure pumps are two duty and one standby that pump to the ARW reservoir. Each pump has a duty of 84.5 L/s at 94 m head.

The high-pressure system, in its normal operation mode, pumps water to the farmlands adjacent to the Aqaba airport, Al-Salam and Al-Haq. During low irrigation demand, excess water will be stored in the ARW reservoir. When the reservoir reaches its full level, the high-pressure pumps will turn off, and farms will be served from the reservoir by gravity. As the water level in the reservoir drops to a pre-determined level, the high-pressure pumps will resume operation.

Turnouts were provided at various locations of the high-pressure force main for future connection to farmlands.

The low-pressure pumps, currently out of service, are one duty and one standby. The low-pressure pumps were designed to supply the existing irrigation users near the WWTP, Riyadi and Nakheel, and convey excess water to the existing wildlife refuge ponds. Each low-pressure pump has a duty of 84.5 L/s at 23.5 m head.

Urban Reclaimed Water

The existing 12,000 m^3/day capacity urban reclaimed water system was constructed in 2005, and includes a pumping station located at the treatment plant, transmission and distribution pipelines, and a reservoir located in the distribution system.

The pump station has three vertical turbine pumps, two duty and one standby, with a duty of 84.5 L/s at 105 m head. The 7,000 m^3 reservoir provides 12 hours' storage to regulate the fluctuations in demand of the URW System. Space was provided to permit to expand the reservoir by 50 % to a total of 10,500 m^3.

The URW pump station discharges into a piping network that supplies the various green areas within Aqaba and provides utility water for the WWTP. Normal operation of the URW pump station is controlled by the level in the reservoir

The system was originally built such that if the URW system demand is low and the URW reservoir fills, a bypass between the URW and the ARW system will open, allowing the excess URW production to be added to the ARW production. Pressure sustaining valves on the URW system side will limit the flow transferred to the ARW system and ensure that system pressure is maintained in the URW system.

3.7.2 Currently Planned Improvements

Currently, no improvements to the reclaimed water system are planned.

3.7.3 Reclaimed Water Storage

As described above, both the ARW and URW systems have provisions to store water during periods of low demand. The MWH Report further pointed out that "if the total demand of the two reclaimed water systems is insufficient to consume the entire production, the levels in the three facultative ponds can be raised by 0.25m. This provides additional storage equal to just over two days average inflow to the two plants and should be sufficient to handle short-term surpluses."

AWC reports that they currently have 100,000 m^3 of reclaimed water storage available and is currently constructing another 30,000 m^3.

3.7.4 Reclaimed Water Distribution System Water Quality

Fecal coliform bacteria such as e-coli will not likely "re-grow" in reclaimed water distribution systems regardless of retention time or water temperature. Once treated or inactivated at the wastewater treatment plant, any remaining e-coli will eventually die off. However, other bacteria often referred to as "opportunistic pathogens" re-grow at variable rates depending on residence time and temperature.

The United States Environmental Protection Agency published "Guidelines for Water Reuse" in September, 2004. Table 4-13 of this publication offers "Suggested Guidelines for Water Reuse" that suggests the maintenance of a chlorine residual of 0.5 mg/L or greater in the reclaimed water distribution system to "reduce the possibility of odors, slime, and bacterial regrowth" in urban landscape irrigation applications. AECOM's experience in the United States is that this guideline is not generally followed.

Bacterial regrowth in the URW distribution and storage system in Aqaba is very likely. The extent of this microbial activity is unknown. Typically, heterotrophic plate counts (HPCs) are used to quantify the extent of the problem. If ASEZA has determined that the amount of regrowth is unacceptable, the following techniques have proven to be effective in reducing reclaimed water distribution system regrowth in irrigation systems:

- Periodic flushing of the distribution system
- Adding disc filters at the point of use
- Maintaining a minimum chlorine residual concentration

4.0 WATER DEMAND PROJECTIONS

4.1 Introduction

The potable water demand projections in this report are based on the Aqaba City Demand Forecast 2011 prepared by AWC. Wastewater generation will be estimated as a percentage of potable water demand, and the reclaimed water demand will be estimated based on existing demands and information collected from prospective developers. The Aqaba WWMP, 2010 and the Aqaba WMP, 2009 provided water demand projections, however, AWC has updated those projections based on recent changes in the economy and development schedules.

The demand forecast in the previous reports considered three scenarios, a low, medium and high projection. This report uses low and high projections to evaluate the range of future reclaimed water flows. The projected flows in each category have two components, natural growth of existing flows, and a portion of the flows from future developments based on current information.

The natural growth of existing flows was assigned low and high growth rates in the Touristic, Commercial, Industrial, Residential, and Agricultural sectors (see Table 4-1 below). Only 60 % of the flow from future developments was assumed to materialize in the low projection, and 90 % in the high projection. Additionally, the percentage of water losses, also referred to as non-revenue water (NRW), was incorporated into the projected rates.

Table 4-1: Natural Growth Rate for High and Low Projections

Sector	Low Projection Growth (%)	High Projection Growth (%)
Touristic	8 %	10 %
Commercial	5 %	7 %
Industrial	0 %	1 %
Residential	3%	4 %
Agricultural	1 %	4 %
Future Developments (Flow Realized)	60 %	90 %

Despite the fact that AWC Demand Forecast identifies known potential developments with their water demands, it only considers in their evaluation what is called a “Verified List.” The Marsa Zayed development and King Hussein Airport expansion were not initially on the verified list. However, these two developments are included in the projections that follow.

4.2 Description of Service Areas

The study area was divided into North and South service areas, solely based on planned association with wastewater treatment plants: the existing wastewater treatment plant in the north and the proposed wastewater treatment plant in the south. The current service area for the existing treatment plant spans between the airport in the north and the port in the south. As mentioned earlier, the existing port will be moved to the south, and the Marsa Zayed development will replace it. The MWH 2010 report evaluated three options for conveying wastewater flows from Marsa Zayed to treatment facilities. The first two options presented infrastructure modifications required to bring the flow to the existing wastewater treatment facilities in the north. The third option provided a concept design for directing the flow to a new wastewater treatment plant in the south. Due to the costs associated with implementing the third option, the plan recommended that the flows from Marsa Zayed be treated by expanding the north wastewater treatment plant. Based on that evaluation, this report includes the future wastewater generated by the Marsa Zayed development flowing into the north service area.

The southern edge of Marsa Zayed establishes the divide between the North and South Service Areas. See Figure 4-1.

4.3 North Service Area

The north service area includes the area between the King Hussein International Airport and the existing port. The existing port, which is planned to be moved to the south, will be replaced by the Marsa Zayed development. Therefore, water demands from all sources north of the southern boundary of Marsa Zayed will be included with the northern service areas demands.

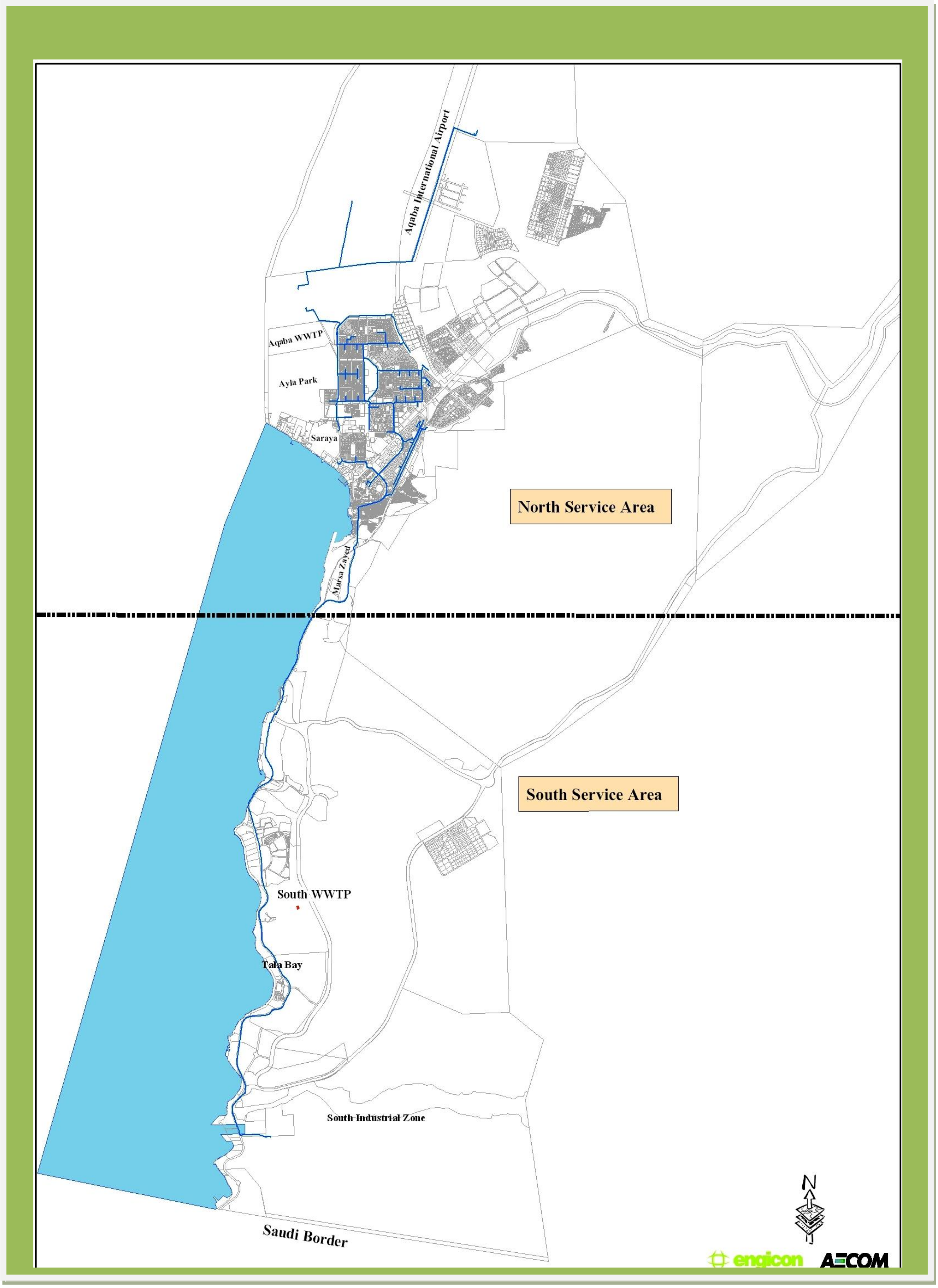

Figure 4-1: North and South Service Areas

4.3.1 Potable Water Demands

Existing Demands

Existing demands are shown in Table 4-2, according to AWC records.

Table 4-2: Existing Demands in the North Service Area – Year 2010

Category	Water Demand MCM/YEAR
Touristic	0.92
Commercial	3.36
Industrial	0.47
Residential	4.07
Agricultural	0.20
Total	**9.02**

Future Developments

The verified developments anticipated to be located in the North Service Area over the next twenty years are listed in the Table 4-3.

Table 4-3: Verified Developments in the North Service Area

Project Name	Water Demand (M3/DAY)	Use	Phases
ADC North Commercial District	6,000	Commercial	
North Industrial Zone	3,020	Industrial	
North Residential Area	6,030	Residential	1, 2, 3
Green Residential Area	3,780	Residential	
Ayla	5,381	Touristic	1, 2, 3
Saraya	3,215	Touristic	
Marsa Zayed	19,044	Touristic	multiple
King Hussain Airport	150	Commercial	

Future Demands

As discussed, there are low and high demand projections for Aqaba, based on the assumption mentioned earlier in this section. See Table 4-4.

Table 4-4: Low Demand Projection in the North Service Area (MCM/YEAR)

	Category	2010	2015	2020	2025	2030
Existing	Touristic	0.92	1.36	2.00	2.93	4.31
	Commercial	3.36	4.28	5.47	6.98	8.91

Table 4-4: Low Demand Projection in the North Service Area (MCM/YEAR)

	Category	2010	2015	2020	2025	2030
	Industrial	0.47	0.47	0.47	0.47	0.47
	Residential	4.07	4.72	5.47	6.34	7.35
	Agricultural	0.20	0.21	0.22	0.23	0.24
New Developments	Touristic	0.00	0.66	2.16	2.76	4.56
	Commercial	0.00	0.91	1.35	1.35	1.35
	Industrial	0.00	0.22	0.66	0.66	0..66
	Residential	0.00	0.06	1.60	2.15	2.15
	Agricultural	0.00	0.00	0.00	0.00	0.00
Total Flows	Touristic	0.92	2.02	4.16	5.69	8.87
	Commercial	3.36	5.19	6.81	8.32	10.25
	Industrial	0.47	0.69	1.13	1.13	1.13
	Residential	4.07	4.78	7.06	8.49	9.50
	Agricultural	0.20	0.21	0.22	0.23	0.24
Sum	**-**	**9.02**	**12.89**	**19.38**	**23.86**	**30.00**
NRW (%)	-	23 %	18 %	13 %	10 %	10 %
NRW (Amount)	-	2.66	2.78	2.84	2.58	3.25
Production	**-**	**11.68**	**15.67**	**22.22**	**26.45**	**33.24**

Table 4.5: High Demand Projection in the North Service Area (MCM/YEAR)

	Category	2010	2015	2020	2025	2030
Existing	Touristic	0.92	1.49	2.40	3.86	6.22
	Commercial	3.36	4.71	6.60	9.26	13.99
	Industrial	0.47	0.49	0.52	0.55	0.57
	Residential	4.07	4.95	6.02	7.33	8.91
	Agricultural	0.20	0.24	0.29	0.35	0.43
New Developments	Touristic	0.00	0.99	3.24	4.14	6.85
	Commercial	0.00	1.36	2.02	2.02	2.02
	Industrial	0.00	0.33	0.99	0.99	0.99
	Residential	0.00	0.09	2.39	3.22	3.22
	Agricultural	0.00	0.00	0.00	0.00	0.00
Total Flows	Touristic	0.92	2.48	5.64	8.00	13.07
	Commercial	3.36	6.07	8.62	11.28	15.01
	Industrial	0.47	0.82	1.51	1.54	1.57
	Residential	4.07	5.04	8.42	10.55	12.14

Table 4.5: High Demand Projection in the North Service Area (MCM/YEAR)

	Category	2010	2015	2020	2025	2030
	Agricultural	0.20	0.24	0.29	0.35	0.43
Sum	-	9.02	14.66	24.48	31.72	42.21
NRW (%)	-	23 %	20 %	18 %	15 %	13 %
NRW (Amount)	-	2.66	3.73	5.29	5.72	6.18
Production	**-**	**11.68**	**18.38**	**29.77**	**37.44**	**48.39**

Figure 4-2 compares the low and high demand projections. It is evident that the high projection has higher natural growth rates, with the 2030 projected demands of 33.24 and 48.39 MCM/year under the low and high scenarios, respectively, making the high projection approximately 46 % higher than the low projection in the year 2030. A major increase in water demand, even under the low projections, is due to the projected developments in the area.

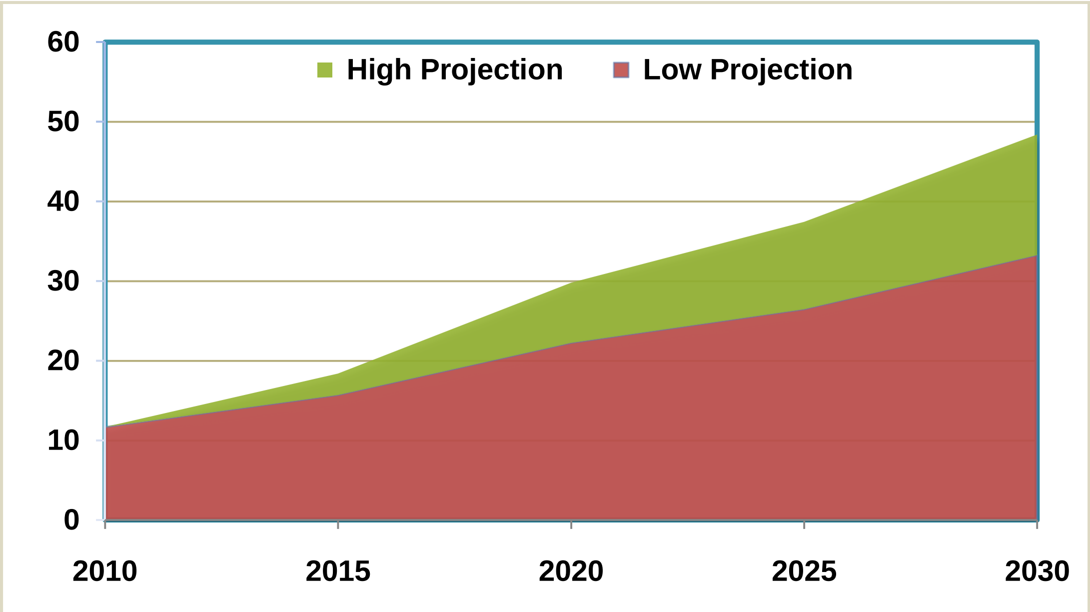

Figure 4-2: Comparison of High and Low Potable Water Demand Projections in the North Service Area

4.3.2 Wastewater Flows

According to AWC's demand forecast, it was assumed the industrial and agricultural demands do not contribute to the wastewater flows. For the contributing sectors, 85 percent of the demand was assumed to be discharged to the wastewater collection system. Shown in Tables 4-6 and 4-7 are the wastewater flows based on both the low and high projections.

Table 4-6: Low Wastewater Projection in the North Service Area (MCM/YEAR)

	Category	2010	2015	2020	2025	2030
Total	Touristic	0.79	1.72	3.53	4.84	7.54

Table 4-6: Low Wastewater Projection in the North Service Area (MCM/YEAR)

	Category	2010	2015	2020	2025	2030
Wastewater Flows	Commercial	2.85	4.41	5.79	7.08	8.71
	Industrial	0.00	0.00	0.00	0.00	0.00
	Residential	3.46	4.06	6.00	7.21	8.07
	Agricultural	0.00	0.00	0.00	0.00	0.00
Sum	**-**	**7.10**	**10.19**	**15.33**	**19.13**	**24.33**

Table 4-7: High Wastewater Projection in the North Service Area (MCM/YEAR)

	Category	2010	2015	2020	2025	2030
Total Wastewater Flows	Touristic	0.79	2.11	4.79	6.80	11.11
	Commercial	2.85	5.16	7.33	9.59	12.76
	Industrial	0.00	0.00	0.00	0.00	0.00
	Residential	3.46	4.28	7.15	8.97	10.32
	Agricultural	0.00	0.00	0.00	0.00	0.00
Sum	**-**	**7.10**	**11.55**	**19.28**	**25.36**	**34.18**

As wastewater flows are dependent on the water demand, it's evident that the high projection has higher growth rates, with the 2030 projected flows of 24.33 and 34.18 MCM/year under the low and high scenarios, respectively, making the high projection approximately 40% higher than the low projection in the year 2030 (See Figure 4-3).

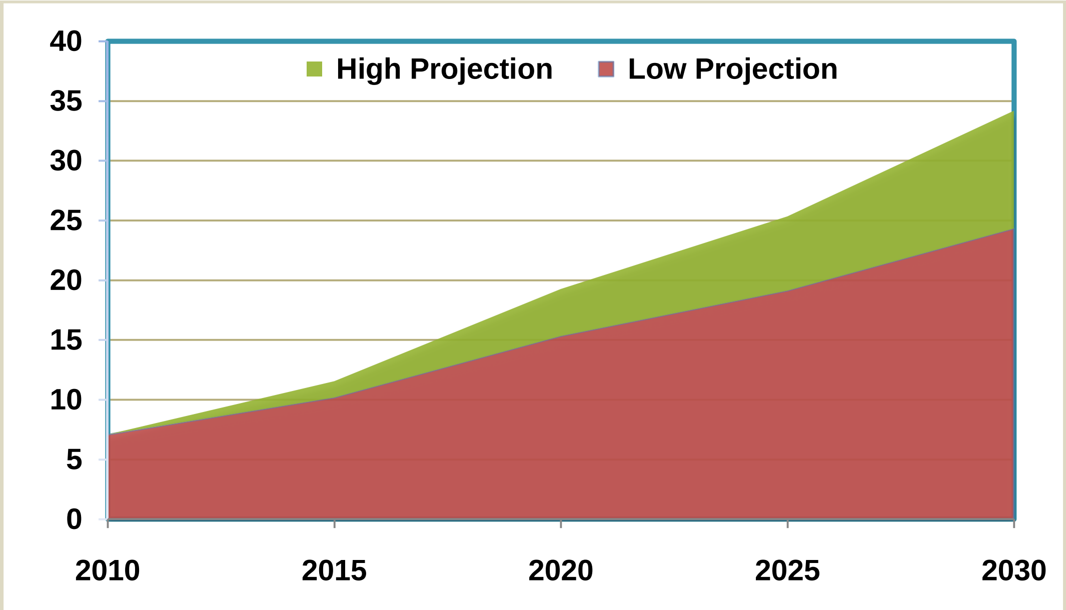

Figure 4-3: Comparison of High and Low Wastewater Demand Projections in the North Service Area

4.3.3 Reclaimed Water Demands

The available reclaimed water, according to AWC's demand forecast, was estimated as 55 percent of the water demand less the industrial and agricultural demands. This is equivalent to 70 percent of the wastewater generated, according to AWC's 2010 reclaimed water report. Shown in the tables below is the available reclaimed water based on both the low and high projections.

Existing Urban Reclaimed Water Demands

According to AWC's reclaimed water report for the year 2010, a total of 2.81 MCM was reused, an average of 7,696 m3/day. The breakdown of URW use is shown in Table 4-8 below.

Table 4-8: URW Usage in 2010

User	URW Used (M^3/Day)
ASEZA	1,988
Treatment Plant	237
Utility	1,310
Jordanian Phosphate Mining Company (JPMC)	4,161
Total URW Used (m^3/day)	**7,696**
Total URW Used (MCM/Year)	**2.81**

Existing Agricultural Reclaimed Water Demands

According to AWC's reclaimed water report for the year 2010, a total of 2.46 MCM was used in irrigation, an average of 6,747 m^3/day. The breakdown of ARW use is shown in Table 4-9.

Table 4-9: ARW Usage in 2010

User	ARW Used (M^3/Day)
Al-Salah+Al-Haq Farms	5,540
Nakheel Farms	472
Riyadi Farms	493
Airport	80
Plant	161
Total ARW Used (m3/day)	**6,747**
Total ARW Used (MCM/Year)	**2.46**

This brings the total reclaimed water demand in 2010 to 5.27 MCM/year. If 70 % of the wastewater generated is reused, we would expect approximately 5.0 MCM (70 % of

7.10 MCM) of reclaimed water to be available. Discrepancies in these numbers are attributed to flow meter accuracy.

Future Reclaimed Water Demands

Reclaimed water is estimated as a percentage of the wastewater generated, approximately 70 percent. Based on the low and high wastewater projections, the corresponding reclaimed water projections are presented in Tables 4-10 and 4-11.

Demand for ARW is not anticipated to increase over the next twenty years. Therefore, all future reclaimed water generated from future wastewater is assumed to be of URW quality.
Also, JPMC demand was assumed to be constant, 1.5 MCM/Year, and will continue to be provided from the existing Wastewater Treatment Plant. Should JPMC demand for URW be met from another source, the balance will be available for use in the North Service Area.

Table 4-10: Low Reclaimed Water Projections in the North Service Area (MCM/Year)

	2010	2015	2020	2025	2030
Wastewater Flow	7.10	10.19	15.33	19.13	24.33
Reclaimed Water (70 %)	4.97	7.13	10.73	13.39	17.03
ARW (Existing)	(2.46)	(2.46)	(2.46)	(2.46)	(2.46)
Net URW Generated	**2.51**	**4.67**	**8.27**	**10.93**	**14.57**

Table 4-11: High Reclaimed Water Projections in the North Service Area (MCM/Year)

	2010	2015	2020	2025	2030
Wastewater Flow	7.10	11.55	19.28	25.36	34.18
Reclaimed Water (70 %)	4.97	8.09	13.49	17.75	23.93
ARW (Existing)	(2.46)	(2.46)	(2.46)	(2.46)	(2.46)
Net URW Generated	**2.51**	**5.63**	**11.03**	**15.29**	**21.47**

Future demands for URW consist of increase in ASEZA landscaping, fixed demand from JPMC, and proposed demands from Saraya and Ayla, as shown in Table 4-12.

Table 4-12: Future Demands for URW (MCM/Year)

	Existing	Future
ASEZA Landscaping	0.73	3.6
JPMC	1.52	1.5 (Assumed)
Treatment Plant	0.09	0.09 (Assumed)
Utility	0.48	0.48 (Assumed)
Saraya (Source: Developer)	0	1.1

Table 4-12: Future Demands for URW (MCM/Year)

	Existing	Future
Ayla (Source: Developer)	0	0.18 Landscaping 1.8 Golf Course
URW Demand	**2.82**	**12.20**

Our understanding from ASEZA is that despite the fact that only 0.73 MCM is currently used for landscaping, their existing demand is 1.6 MCM/year. ASEZA is only receiving the lesser amount due to constraints on the availability of URW. ASEZA's ultimate need to URW for landscaping is 3.6 MCM/year.

Comparing the urban reclaimed water projections and demands, there is no significant surplus under the low projections, while there is a surplus of approximately 6.0 MCM/Year under the high projection.

As detailed earlier, Saraya has a completion date of 2014, while Ayla has a completion date of 2015 and 2019 for phases 1 and 2, and start date of 2020 for the last phase. These dates impact their demand for URW. In the case of Ayla, their demand for 1.8 MCM/year for the golf course was not associated with a certain phase.

Also, future developments in the north service area, such as the airport and north industrial zone, could potentially have a need for URW, but providing such developments with URW could be faced with limitations of existing infrastructure.

4.4 South Service Area

The south service area includes the area between the existing port and the Saudi Border.

4.4.1 Potable Water Demands

Existing Demands

Existing water demands are shown in Table 4-13, according to AWC records.

Table 4-13: Existing Demands in the South Service Area - Year 2010

Category	Water Demand MCM/Year
Touristic	0.00
Commercial	1.00
Industrial	3.00
Residential	0.00
Agricultural	0.00
Total	**4.00**

It is evident that the current industrial sector, mainly JPMC and Kimera, is consuming approximately 75 % of the water in the south service area. The industrial sector has a depletive use of water, meaning that none of its consumed water returns back to the municipal wastewater collection system.

Future Developments

The verified future developments in the South Service Area are listed in Table 4-14.

Table 4-14: Verified Future Developments in the South Service Area

Project Name	Water Demand M3/Day	Use	Phases
South Industrial Zone	9,754	Industrial	1,2
South Port	2,210	Industrial	
Arab Fertilizers and Chemicals Industries (Kemapco/Kimera)	1,000	Industrial	
South Residential Village	14,230	Residential	1,2,3
Engineering Association	225	Residential	
Tala Bay	9,000	Touristic	
Yemeniya	2,227	Touristic	E1,2,3 + Medical
Zara Project(South Tourism Village & Beach Hotels)	1,564	Touristic	

Future Demands

As discussed, there are low and high demand projections for Aqaba, based on the assumptions mentioned earlier in this section. See Tables 4-15 and 4-16

Table 4-15: Low Demand Projection in the South Service Area (MCM/Year)

	Category	2010	2015	2020	2025	2030
Existing	Touristic	0.00	0.00	0.00	0.00	0.00
	Commercial	1.00	1.28	1.63	2.08	2.65
	Industrial	3.00	3.00	3.00	3.00	3.00
	Residential	0.00	0.00	0.00	0.00	0.00
	Agricultural	0.00	0.00	0.00	0.00	0.00
New Developments	Touristic	0.00	2.50	2.91	2.91	2.91
	Commercial	0.00	0.00	0.00	0.00	0.00
	Industrial	0.00	1.04	1.72	1.72	2.10
	Residential	0.00	0.53	2.11	3.17	3.17
	Agricultural	0.00	0.00	0.00	0.00	0.00
Total Flows	Touristic	0.00	2.50	2.91	2.91	2.91
	Commercial	1.00	1.28	1.63	2.08	2.65
	Industrial	3.00	4.04	4.72	4.72	5.10

Table 4-15: Low Demand Projection in the South Service Area (MCM/Year)

	Category	2010	2015	2020	2025	2030
	Residential	0.00	0.53	2.11	3.17	3.17
	Agricultural	0.00	0.00	0.00	0.00	0.00
Sum	**-**	**4.00**	**8.35**	**11.38**	**12.88**	**13.83**
NRW (%)	-	23 %	18 %	13 %	10 %	10 %
NRW (Amount)	-	1.18	1.80	1.67	1.39	1.50
Production	**-**	**5.18**	**10.15**	**13.04**	**14.27**	**15.32**

Table 4-16: High Demand Projection in the South Service Area (MCM/Year)

	Category	2010	2015	2020	2025	2030
Existing	Touristic	0.00	0.00	0.00	0.00	0.00
	Commercial	1.00	1.40	1.97	2.76	3.87
	Industrial	3.00	3.15	3.31	3.48	3.66
	Residential	0.00	0.00	0.00	0.00	0.00
	Agricultural	0.00	0.00	0.00	0.00	0.00
New Developments	Touristic	0.00	3.75	4.37	4.37	4.37
	Commercial	0.00	0.00	0.00	0.00	0.00
	Industrial	0.00	1.56	2.58	2.58	3.14
	Residential	0.00	0.80	3.17	4.75	4.75
	Agricultural	0.00	0.00	0.00	0.00	0.00
Total Flows	Touristic	0.00	3.75	4.37	4.37	4.37
	Commercial	1.00	1.40	1.97	2.76	3.87
	Industrial	3.00	4.72	5.90	6.07	6.80
	Residential	0.00	0.80	3.17	4.75	4.75
	Agricultural	0.00	0.00	0.00	0.00	0.00
Sum	**-**	**4.00**	**10.66**	**15.41**	**17.94**	**19.79**
NRW (%)	-	23%	20%	18%	15%	13%
NRW (Amount)	-	1.18	2.71	3.33	3.23	2.90
Production	**-**	**5.18**	**13.37**	**18.73**	**21.18**	**22.69**

Comparing the low and high demand projections, it's evident that the high projection has higher growth rates, with the 2030 projected demands of 15.32 and 22.69 MCM/year under the low and high scenarios, making the high projection approximately 48 % higher than the low projection in the year 2030. Major increases in water demand, even under the low projections, is due to the projected developments in the area. See Figure 4-4.

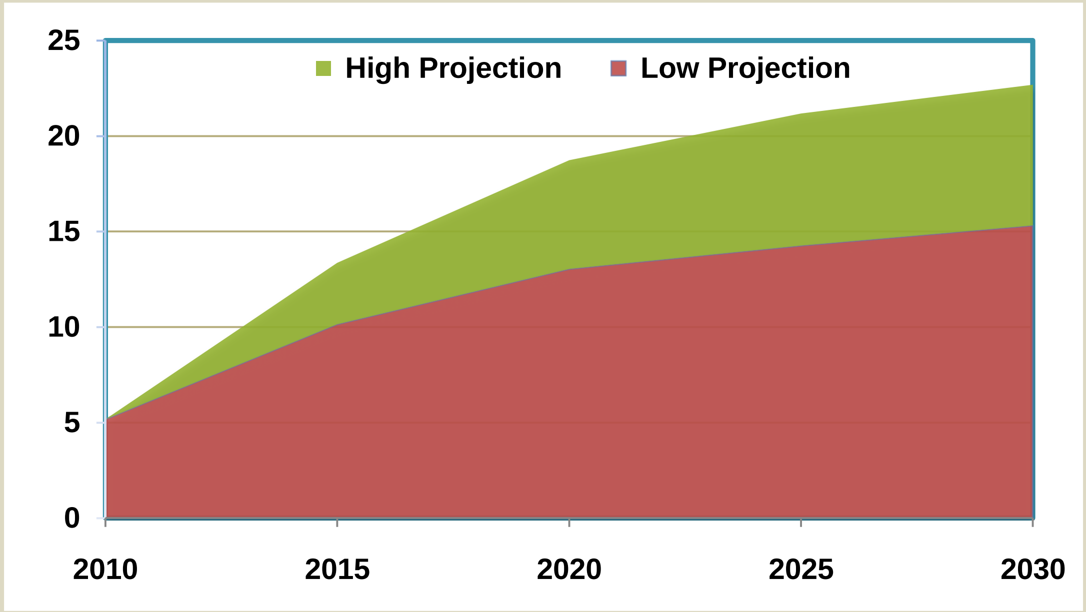

Figure 4-4: Comparison of High and Low Potable Water Demand Projections in the South Service Area

4.4.2 Wastewater Flows

According to AWC's demand forecast, it was assumed the industrial and agricultural demands do not contribute to the wastewater flows. For the contributing categories, 85 percent was assumed to contribute to the wastewater flows. Shown in Tables 4-17 and 4-18 are the wastewater flows based on both the low and high projections.

Table 4-17: Low Wastewater Projection in the South Service Area (MCM/Year)

	Category	2010	2015	2020	2025	2030
Total Wastewater Flows	Touristic	0.00	2.12	2.48	2.48	2.48
	Commercial	0.85	1.08	1.38	1.77	2.26
	Industrial	0.00	0.00	0.00	0.00	0.00
	Residential	0.00	0.45	1.80	2.69	2.69
	Agricultural	0.00	0.00	0.00	0.00	0.00
Sum	**-**	**0.85**	**3.66**	**5.66**	**6.93**	**7.42**

Table 4-18: High Wastewater Projection in the South Service Area (MCM/Year)

	Category	2010	2015	2020	2025	2030
Total Wastewater Flows	Touristic	0.00	3.19	3.71	3.71	3.71
	Commercial	0.85	1.19	1.67	2.35	3.29
	Industrial	0.00	0.00	0.00	0.00	0.00
	Residential	0.00	0.68	2.70	4.04	4.04
	Agricultural	0.00	0.00	0.00	0.00	0.00
Sum	**-**	**0.85**	**5.05**	**8.08**	**10.09**	**11.04**

As wastewater flows are dependent on the water demand, it's evident that the high projection has higher growth rates, with the 2030 projected flows of 7.42 and 11.04 MCM/year under the low and high scenarios, making the high projection approximately 49% higher than the low projection in the year 2030. Major increases in wastewater flows, even under the low projections, are due to the projected developments in the area. See Figure 4-5.

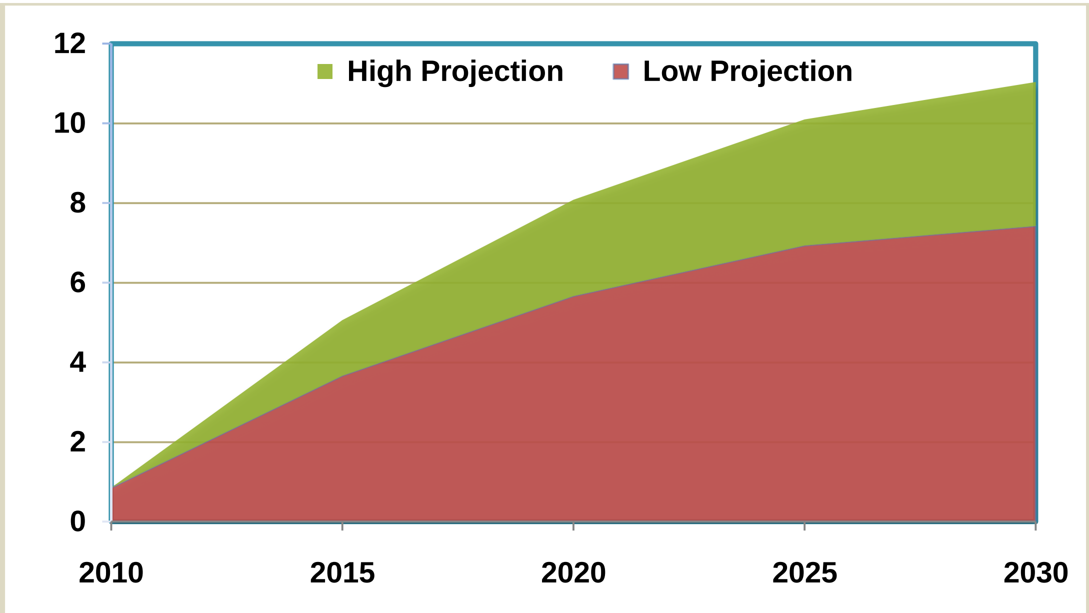

Figure 4-5: Comparison of High and Low Wastewater Demand Projections in the South Service Area

4.4.3 Reclaimed Water Demands

The available reclaimed water, according to AWC's demand forecast, was estimated as 55 percent of the water demand less the industrial and agricultural demands. This is equivalent to 70 percent of the wastewater generated, according to AWC's 2010 reclaimed water report. Shown in the tables below (Tables 4-19 and 4-20) are the available reclaimed water based on both the low and high projections.

Existing Urban Reclaimed Water Demands

JPMC is the only user for URW in the South Service Area using approximately 1.5 MCM/year, according to AWC's 2010 records. JPMC was assumed to continue receiving its allocated amount from the North Service Area. There is no other existing use of reclaimed water in the South Service Area.

Existing Agricultural Reclaimed Water Demands

There is no existing use of ARW in the south service area.

Future Reclaimed Water Demands

As discussed earlier, URW is estimated as a percentage of the wastewater generated, approximately 70 percent. Based on the low and high wastewater projections, the corresponding reclaimed water projections are presented below.

Earlier assumptions made for the North Service Area are valid for the South Service Area; there will be no demand for ARW in the south, and that all reclaimed water generated from additional wastewater is assumed to be of URW quality.

Also, JPMC demand was assumed to be constant, 1.5 MCM/Year, and will continue to be provided from the North Wastewater Treatment Plant. As mentioned earlier, it is assumed that no water will be reclaimed from the industrial sector, consisting primarily of JPMC and Kimera.

Table 4-19: Low Reclaimed Water Projections in the South Service Area (MCM/Year)

	2010	2015	2020	2025	2030
Wastewater Flow	0.85	3.66	5.66	6.93	7.42
Reclaimed Water (70 %)	0.60	2.56	3.96	4.85	5.19
ARW (Existing)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
Net URW Generated	**0.60**	**2.56**	**3.96**	**4.85**	**5.19**

Table 4-20: High Reclaimed Water Projections in the South Service Area (MCM/Year)

	2010	2015	2020	2025	2030
Wastewater Flow	0.85	5.05	8.08	10.09	11.04
Reclaimed Water (70 %)	0.60	3.54	5.66	7.07	7.73
ARW (Existing)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
Net URW Generated	**0.60**	**3.54**	**5.66**	**7.07**	**7.73**

Besides JPMC, there is a possibility that industries in the south service area will use URW. In addition to demand from industries, it was assumed that landscaping will constitute a major future demand for URW in this service area.

Also, as the projected wastewater flows are generated from the touristic, commercial and residential sectors, AWC has will have URW available for each development equivalent to a percentage of wastewater flow generated from that development.

It was assumed that there will be no demand for ARW in the south service area.

5.0 EVALUATION OF RECLAIMED WATER SYSTEMS

5.1 Model Development

As presented in the previous sections, the existing reclaimed water system in Aqaba consists of two independent systems: the agricultural reclaimed water (ARW) system and the urban reclaimed water (URW) system. In order to assess the capacities of these systems under various demand conditions, a hydraulic model was developed for the two systems.

The ARW model consists of a 51,000 m^3 reservoir, a storage tank that feeds the farms via gravity during low irrigation demands, and two pumps. The ARW network serves the farms and airport irrigation demands. A schematic diagram of the ARW model is illustrated in Figure 5-1.

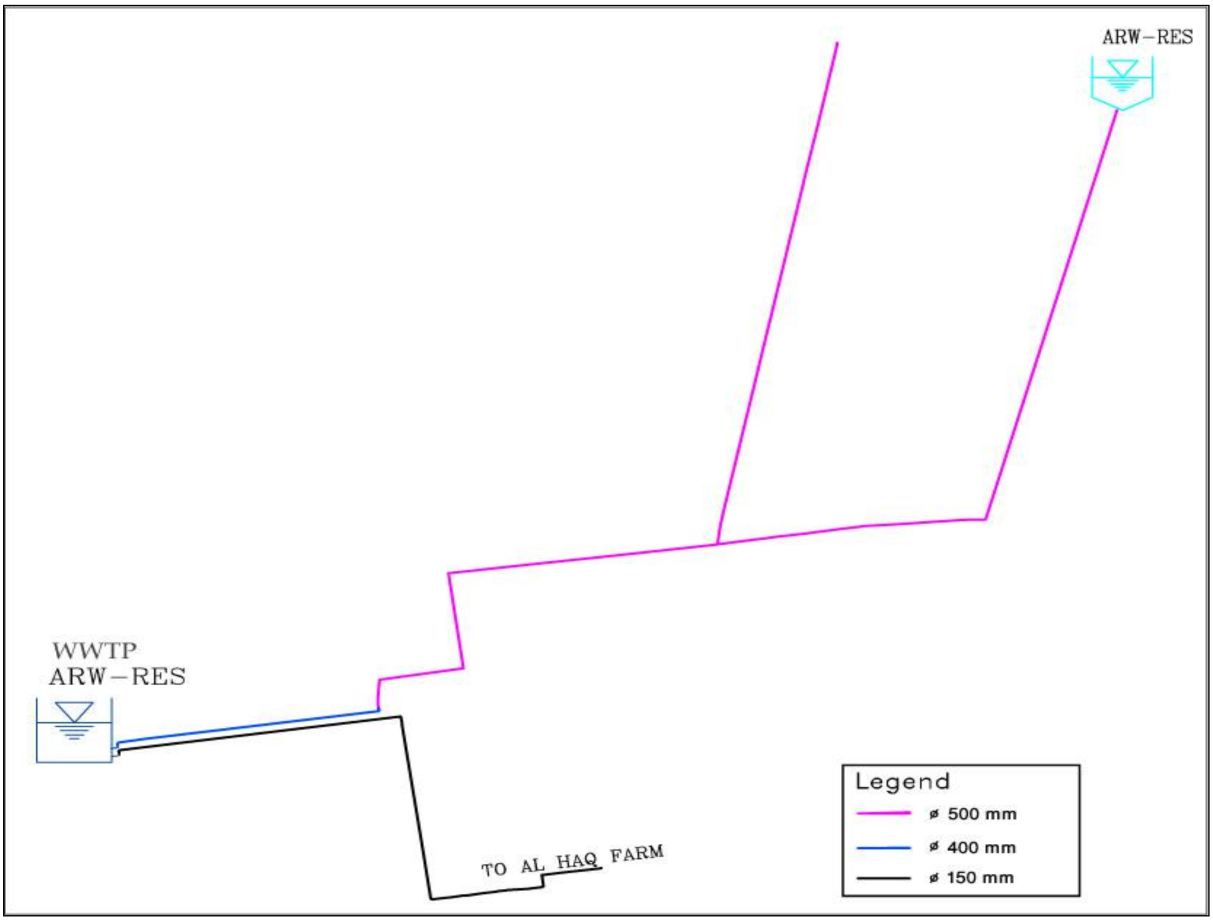

Figure 5-1: ARW system schematic diagram

The URW model comprises the following components:

- URW Reservoir at the WWTP (used as a wet well for the pumping station)
- URW pumps at the URW Reservoir, including one standby pump and two duty pumps of 105m head and 84.5 l/s flow
- URW Tank 7000 m^3, located at 9^{th} Residential area
- JPM Tank located at south industrial zone
- A network of pipes ranging in diameter between 150 mm and 600 mm

A schematic diagram of the URW model is presented in Figure 5-2.

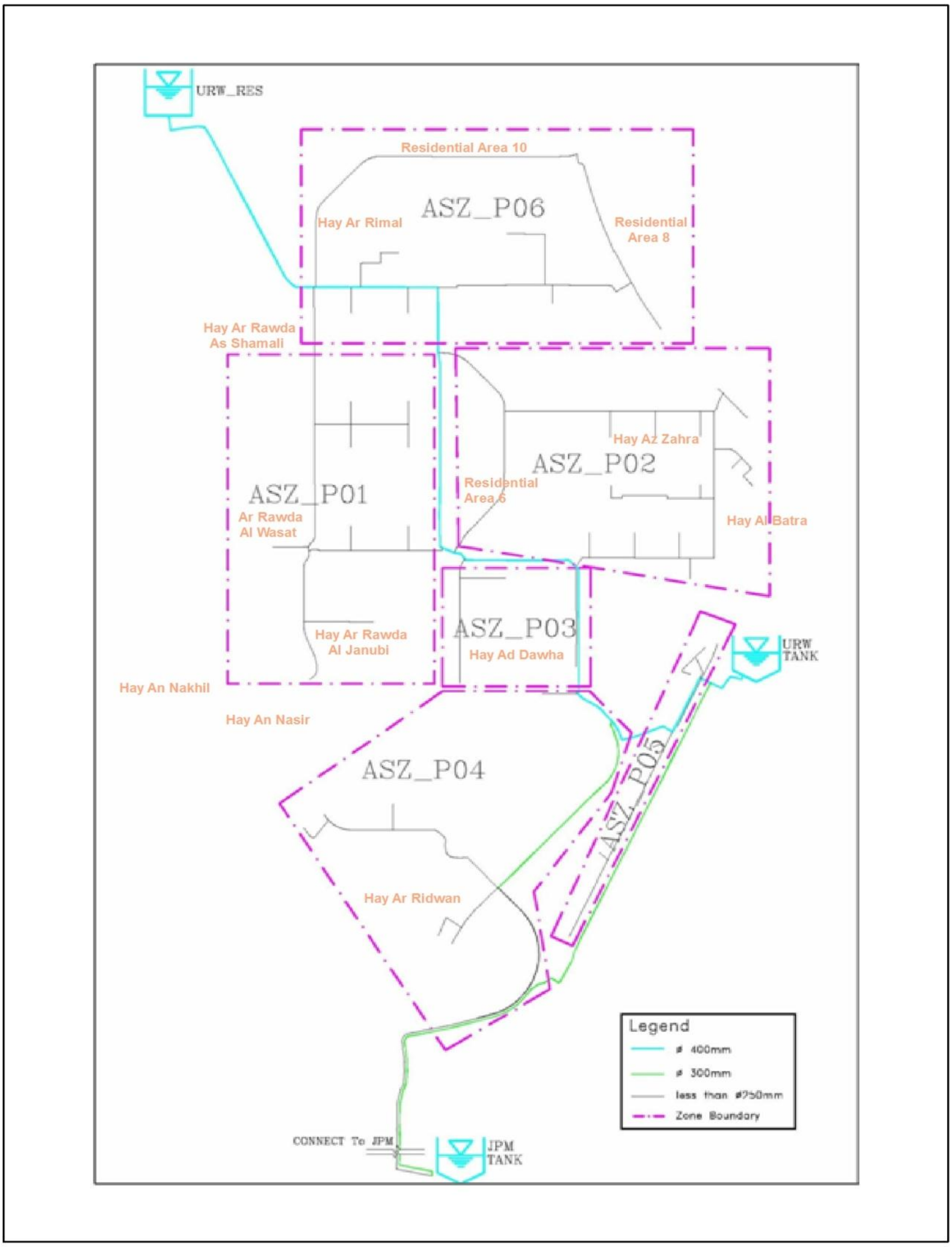

Figure 5-2: URW system schematic diagram

In order to assess the capacity of the reclaimed water system under various demand conditions, a hydraulic model was developed to simulate the ARW and URW systems. The hydraulic modeling of the reclaimed water systems was carried out using the H2ONET computer analysis program. The network, pump configuration, and water tanks information was derived from the as-built drawings provided by AWC. Ground elevations for the junctions were derived from ground levels in an existing model. Obtaining more accurate ground elevations from AWC was not possible in order to verify these levels.

The demand junctions in the model represent JPMC, ASEZA landscaping turnouts, the Airport, and the farms. The ASEZA landscape irrigation demands are represented in the model by 117 demand junctions. Because of the lack of information detailing the demand associated with each turnout, the total reclaimed water billed to ASEZA in 2010 was divided evenly among all 117 junctions. The ASEZA turnout locations were determined using the as-built drawings provided by AWC. The reclaimed water demands representing the existing use (referred to below as the baseline demands) are summarized in Table 5-1.

Table 5-1: Existing reclaimed water demands

Area	Demand (l/s)
ASEZA Landscape	30.0
JPMC	48.0
Airport	1.26
Farms	75.3

Another aspect associated with the demand is the diurnal pattern. In the absence of more precise information about the ASEZA irrigation demand distribution and pattern, the turnouts were grouped under six demand zones, The zones selected for the purpose of network modeling represent geographical locations in Aqaba, each of which is served by a URW network loop branching from the main supply pipeline. Each zone was assigned a diurnal that limits zone irrigation to 3 hours per day. The demand patterns assigned to the six irrigation zones did not overlap; they were back to back. The JPMC, Airport and Farms were assigned a flat diurnal pattern. The Table 5-2 summarizes the demand information simulated for each of ASEZA's six irrigation zones.

Table 5-2: Demand distribution of the ASEZA irrigation system

Zone	No. of turnouts	Total demand l/s	Diurnal time allocation (hr)
ASZ – P01	11	2.86	06:00 – 09:00
ASZ – P02	21	5.46	09:00 – 12:00
ASZ – P03	13	3.38	12:00 – 15:00
ASZ – P04	32	8.32	15:00 – 18:00
ASZ – P05	17	4.42	18:00 – 21:00
ASZ – P06	23	5.98	21:00 – 00:00

The locations of the six zones, identified as ASZ-P01 through ASZ-P06, are shown in Figure 5-2, above.

As discussed earlier, there are two pumping stations; one for the ARW system and the other for the URW system. The ARW pumps are controlled by the water levels in the storage tank at east of airport the URW pumps are controlled by water levels in the storage tank at the Ninth Residential area. For example, when the water level in the ARW tank, located east of the airport, drops below a pre-determined level, the ARW pumps turn on, and when the tank fills to a pre-determined level, those pumps will turn off.

Similarly, for the URW pumps, the pumps are controlled by the water levels in the URW Tank located in the Ninth Residential Area, in Zone P05. When the water level in the URW tank drops below a pre-determined level, the URW pumps at the WWTP turn on, and when the tank fills to a pre-determined level, those pumps will turn off.

An extended period simulation was carried out for the two reclaimed water systems. All pumps were assumed to be off at the beginning of the model run, and the water level in the two tanks was set to full accordingly. With this assumption, at the beginning of the model run, the tanks will be supplying water to the system by gravity until their levels drop to their respective low-level set point. result

5.2 Existing System Evaluation – Baseline Demand Condition

The existing ARW system model was evaluated under the existing ARW demand conditions described in Chapter 3. The model results for the ARW network reveal that the existing network is adequate; all ARW demand junctions have adequate pressures that range between 25 and 80 m, and the network has an adequate range of pipe velocities that does not exceed 1.8 m/s. As discussed earlier, no expansion of farms is expected; hence no increase in demand for ARW is expected.

The existing URW system model described above was evaluated under the existing (baseline) demand condition. The resulting pressures at demand junctions were reviewed in order to identify areas with potential capacity issues. Figure 5.3 is an illustration of the pressures at the network junctions. The junctions with low pressures (<10 m) encountered during the extended period simulation are color-coded in order to facilitate their identification. The junctions with pressures ranging between 0.0 and 10 m are identified with a yellow circle, while those that have exhibited negative pressures are identified with red circles. The junctions with pressures over 10 m are not on identified on the figure since their performance is assumed satisfactory.

As shown in the Figure 5-3, the system maintains satisfactory pressures at the majority of the demand junctions. The pressures in the system ranged between a high of approximately 97 meters to a low of approximately 1.6 meters. The low pressure junctions are located in Zones P02 and P05.

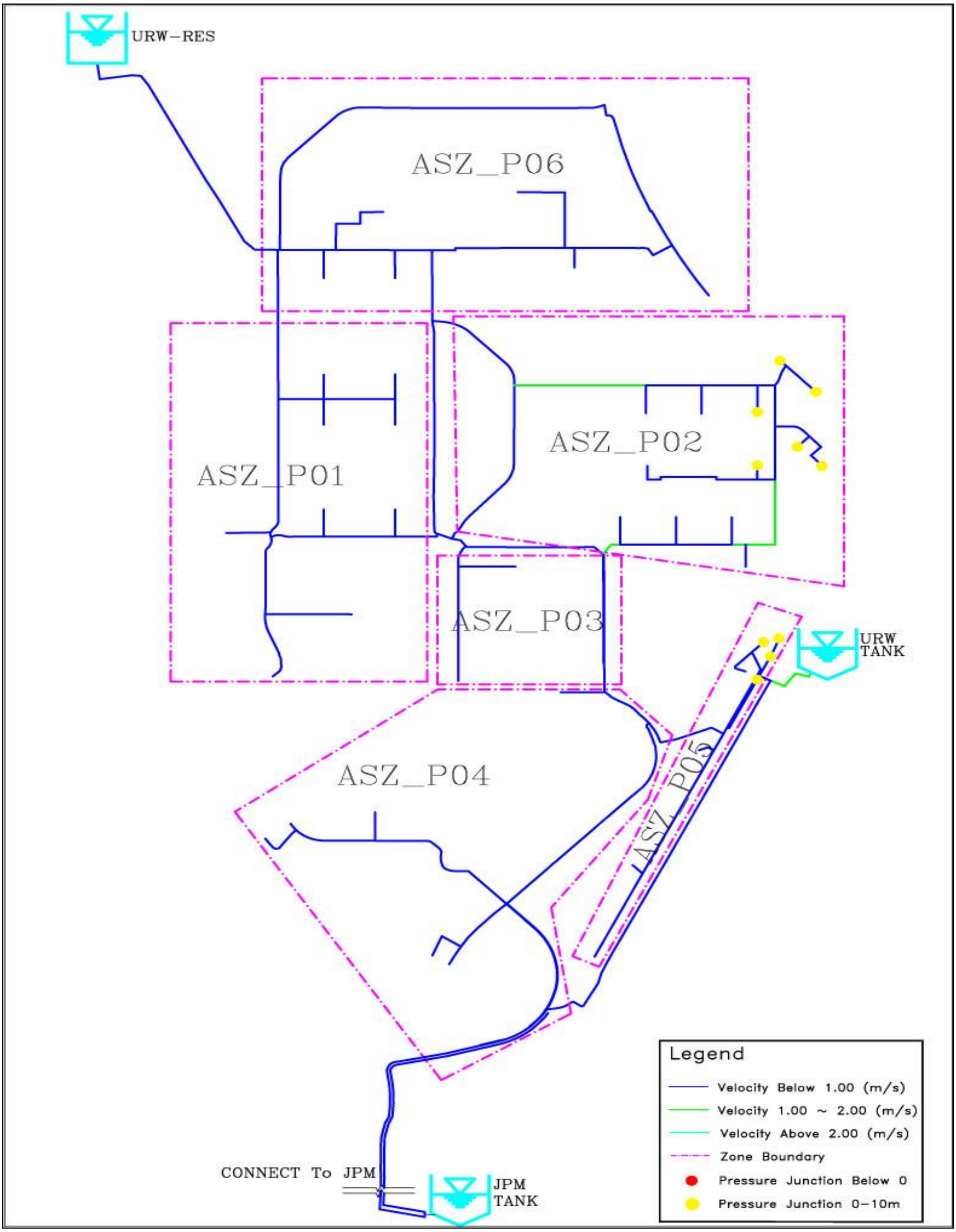

Figure 5-3: ASEZA Baseline URW demand – low pressure junctions

Another measure that was used to identify bottlenecks in the system is velocity. Since the system was evaluated under extended period simulation, the maximum velocity over the simulation period was identified for each pipe segment. Pipes with high velocities form bottlenecks in the system, potentially leading to low pressures as a result of high head losses. The pipes in Figure 5.3 have been color-coded by velocity range in order to identify the segments of the network with excessive flow velocities. As can be observed from Figure 5.3, the majority of the network pipes maintain a velocity of less than 1.0 m/s; some pipes in Zones P02 and P05 show velocities ranging between 1.0 and 2.0 m/s. No velocities in excess of 2.0m were encountered.

5.3 Existing System Evaluation – Future Demand Conditions

5.3.1 Future demand scenarios

Predicting the system performance under future demand conditions is essential in order to identify areas contributing to constraints in system performance, such as low pressures and high velocities. The system simulation will aid in developing recommendations to alleviate those constraints.

Future demands consist of two components: one is the increase in existing demands, and the second is new demands from new developments, namely Saraya and Ayla. Existing JPMC demands were assumed to remain unchanged in the future. The demands for Saraya and Ayala were provided by the developers, as discussed in the previous sections.

ASEZA's future landscaping demand affects the internal distribution network. Information detailing ASEZA future demands for landscaping could not be accurately projected, neither in terms of flow quantities nor in terms of expansion areas. As such, a sensitivity analysis approach was adopted to assess the impact of future increase in ASEZA's landscaping demand on the existing system. Two scenarios have been considered for ASEZA's landscaping future demand: (1) future demands remain as the existing, and (2) future demands being 50 % above the existing demands. In the second scenario, the increase in demand is assumed to remain within the existing Zones P01 to P06, assigned to the same turnouts of the present network, and is equally distributed among the 117 demand junctions, as presented earlier in this section.

Ayla and Saraya flows are considered based on their full development conditions. Accordingly the following simulations have been carried out for the future scenarios of the Urban Reclaimed Water system in Aqaba, assuming that URW reservoir is capable of supplying sufficient flow to meet each of the demand scenarios:

Scenario (1): ASEZA 50 % above baseline demand without Ayla and Saraya
Scenario (2): ASEZA baseline demand + Ayla + Saraya
Scenario (3): ASEZA 50 % above baseline demand with Ayla and Saraya

The model results were examined for the above-mentioned three scenarios, and areas with low pressures and high velocities were identified. The hydraulic modeling results are discussed in the following paragraphs.

5.3.2 Future Scenario (1)

This scenario considers ASEZA's future demand to be 50 % above its baseline demand, without Ayla and Saraya. This scenario represents a situation where Ayla and Saraya will have their own WWTP and they would not be connected either to the existing WWTP or to the existing network.

As such, this simulation assesses the network performance under changes in ASEZA demands only. As discussed earlier in this section, this scenario would be more of a sensitivity analysis to changes in irrigation demands rather than a simulation of a future condition.

The results of the model run for this scenario reveal that some junctions will encounter negative pressure values particularly in Zones P02 and P05, and that the velocities in the distribution pipes will stay below 2.0 m/s. The pressures at the demand junctions and the velocities in the pipes are presented in Figure 5-4. The URW network depicted in the figure is color-coded according to ranges in pressures and velocities in order to facilitate identifying the problem areas.

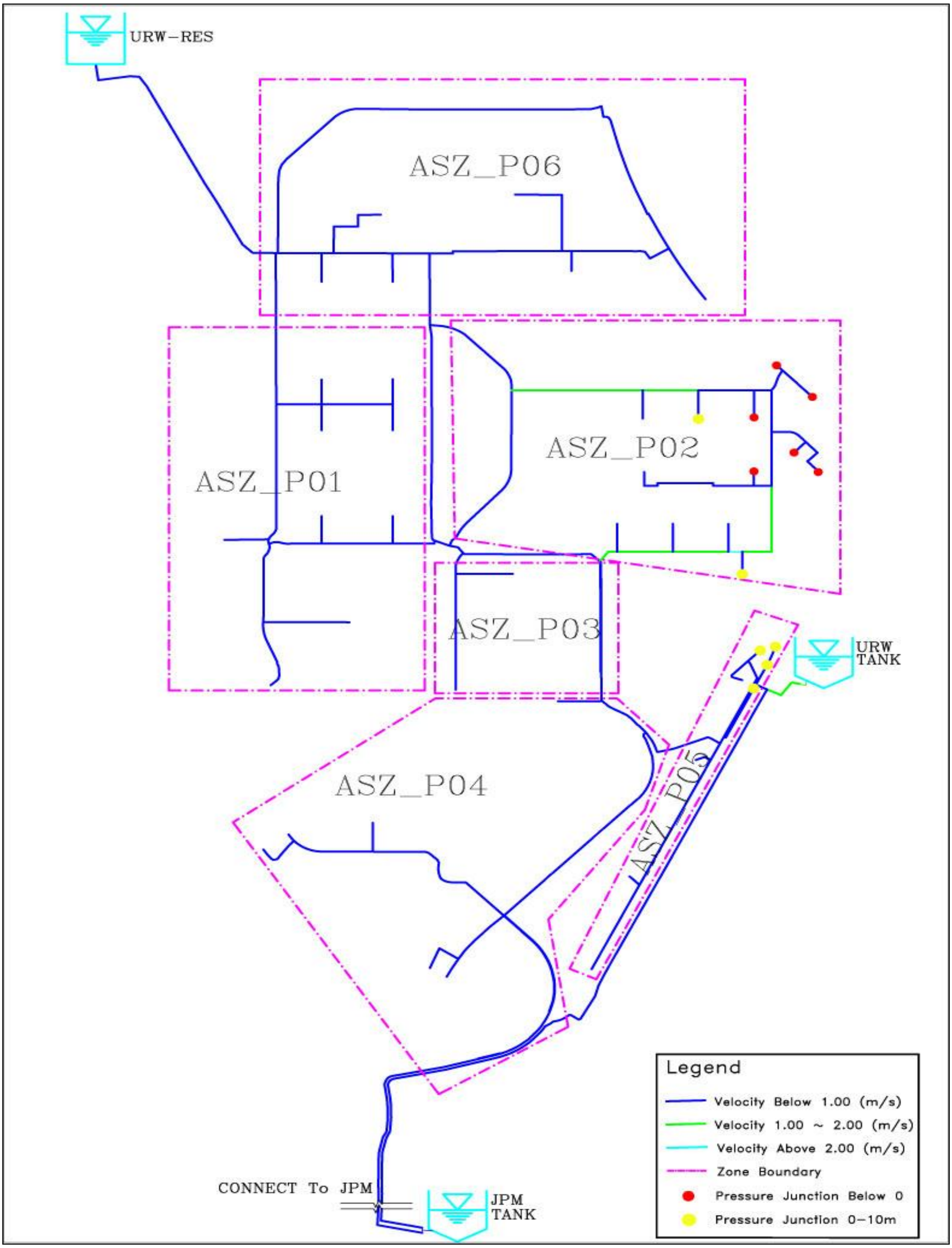

Figure 5-4: Future Scenario 1 – Low pressure and high velocity distribution

5.3.3 Future Scenario (2)

Future Scenario (2) represents ASEZA's baseline demand, plus those of Ayla and Saraya. The new demands for Ayla and Saraya were added to the model at a new demand junction located on the 150 mm pipeline in P01 zone, branching off the 400 mm pipeline. The assumed demand location is illustrated in Figure 5.5.

The model results for future Scenario (2) are illustrated as nodes with low pressures and as velocity distribution in Figure 5.5. The network is also color-coded following typical ranges in pressures and velocities. As may be concluded from Figure 5.5, a negative pressure is now present at the Ayla and Saraya junction, in addition to other low pressure junctions ranging between -1.6 to 4.5 m in Zones P01, P02 and P05.

The Ayla and Saraya new demand will also result in a change to the velocity distribution, where some pipes will encounter velocities higher than 2.0m/s as shown in Figure 5-5. Similar to the low pressure distribution, the high network velocities are encountered in Zones P01 and P05, due to the additional high demands.

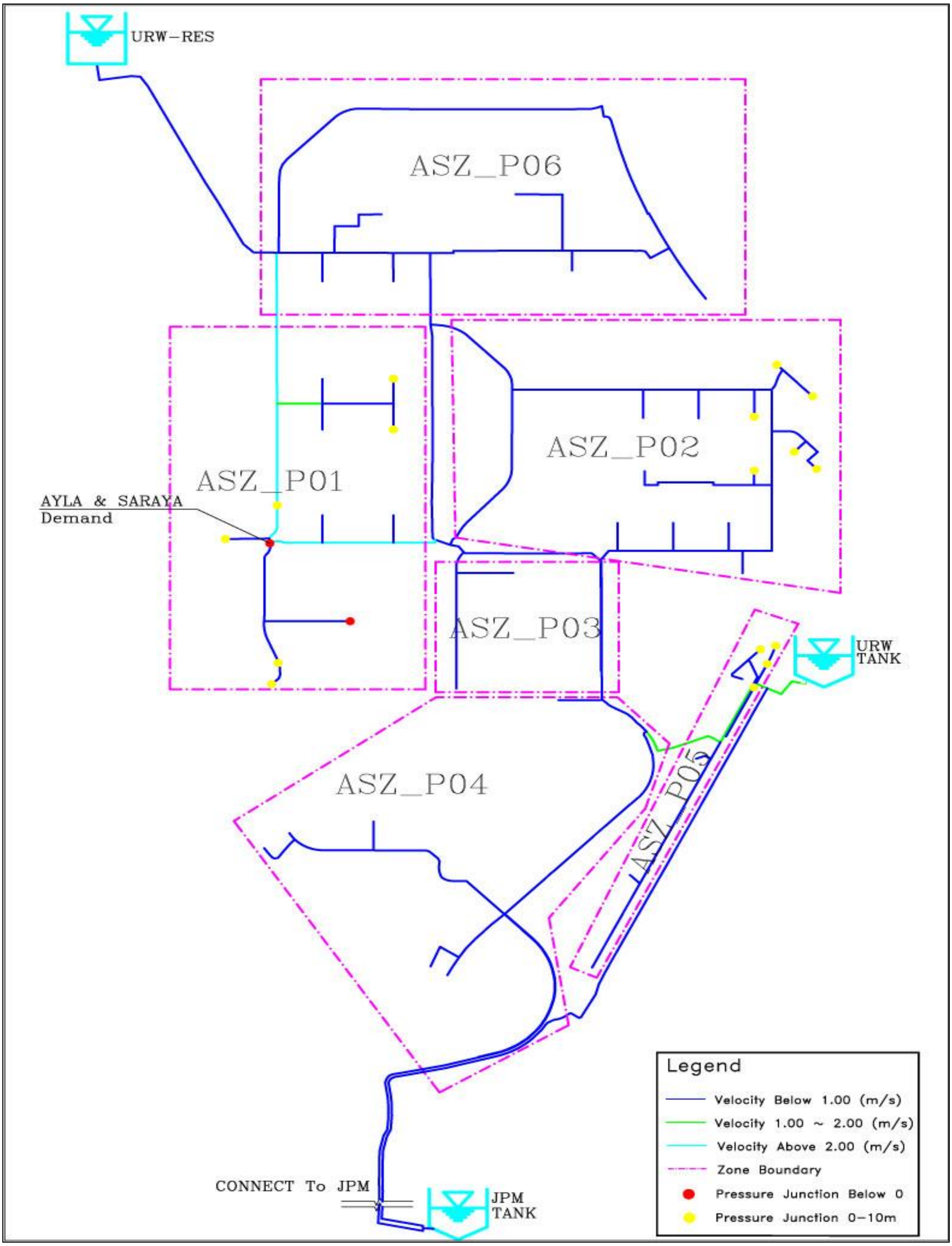

Figure 5-5: Future Scenario 2 – Low pressure and high velocity distribution

5.3.4 Future Scenario (3)

This scenario is a combination of the above two scenarios. It represents the condition where the ASEZA demands are 50 % above baseline demands in addition to Ayla and Saraya demands being located at the 150mm pipeline, in P01 zone. Similar to the above two scenarios, the model results, namely, pressures at demand junctions and velocities in pipes, are presented as a color coded network. As may be concluded from the simulation results depicted in Figures 5-6 below, negative pressure junctions are encountered in this scenario, especially in P01 and P02 zones, and the velocity in the 150 mm pipeline in Zone P01 will exceed 2.0 m/s.

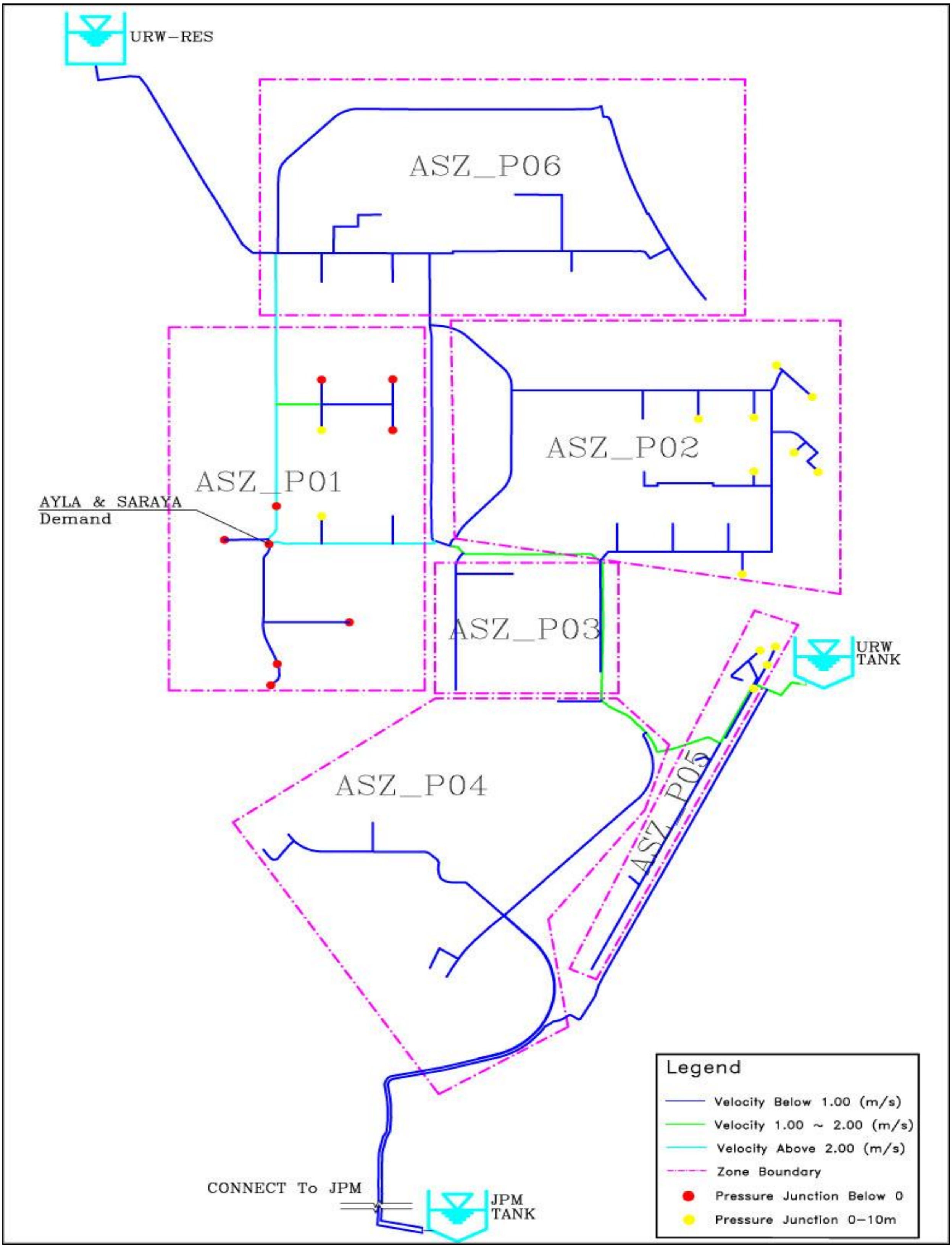

Figure 5-6: Future Scenario 3 – Low pressure and high velocity distribution

5.4 Discussion of Results

5.4.1 Existing System Baseline Demand

The model results for the system baseline condition revealed low pressure values encountered at certain junctions in Zone P02 and around the URW tank area in Zone P05. The tank area in Zone P05 has a high ground elevation, and the low pressure values in that zone are mainly due to topography and not head losses in pipes. As such, improvement to the existing network or modification of irrigation demand patterns in the model may improve the pressures but will not eliminate low pressures at the junctions with high ground levels.

In order to assess the impact of irrigation demand pattern modification, another run was carried out by changing the diurnal pattern presented earlier in Table 5.2: instead of supplying the zones' irrigation demands in 3-hr periods, the supply durations have been extended to be 4-hr periods. Hence, the irrigation time for all six zones becomes 24 hrs instead of 18 hrs.

The revised simulation revealed that some low pressures in Zone P02 could be eliminated, and that would be attributed to the lower flow rates and lower head losses in the network. The low pressures in Zone P05 did not improve since they were due to high ground elevations around the URW reservoir. The schematic diagram of the network with low pressure according to this model run is included as Figure 5-7. The assumed diurnal pattern (3 continuous hours of irrigation per day for each zone) does not have a significant impact on the model results in terms of pressures and velocities within zones P01 to P06.

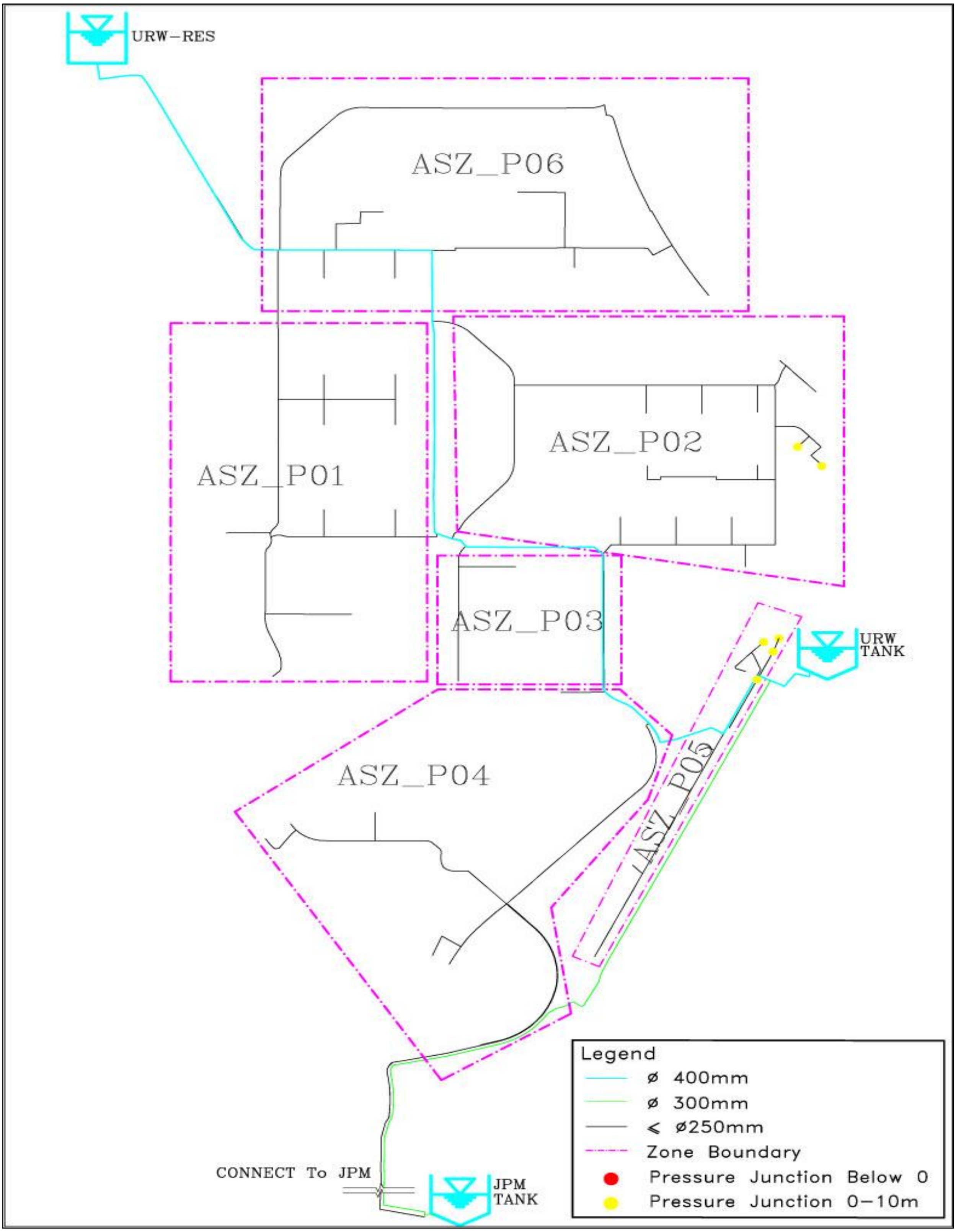

Figure 5-7: ASEZA baseline demand – low pressure junctions – modified diurnal pattern

5.4.2 Future demand (Scenario 1) ASEZA baseline X 1.5 without Ayla and Saraya

Low pressure junctions and many junctions with negative pressure values are present due to head losses in the network pipes arising from the additional ASEZA demand. These junctions are primarily located in Zone P02 of the network. Changing the irrigation pattern, for example from 3-hr pattern to 4-hr pattern, as suggested in paragraph 5.1.4.1, above, will reduce the number of low pressure junctions (i.e. will increase the overall pressures in the network) as a result of the lower head losses but will not eliminate the low pressures or negative pressures completely. Further modifications to the diurnal pattern to address these problems were not attempted because, as mentioned earlier, this is not deemed to be a simulation of a certain future condition of the system but rather a sensitivity analysis on the demand of ASEZA's irrigation system.

5.4.3 Future demand (Scenario 2): ASEZA Baseline demand + Ayla + Saraya

Many low pressure junctions in addition to negative pressure values appear in this scenario. These low and negative pressure values are concentrated near the demand junction of Ayla and Saraya in Zone P01. This drop in pressure is expected due to Ayla and Saraya demand which will cause additional head losses in the 150mm pipeline of the existing network. Upgrade of the existing network, especially the supply pipes that serve Ayla and Saraya, will be required to eliminate the negative pressure values in the network.

Another model simulation has been carried out to assess the upgrade to the existing network to accommodate the new demands of future Scenario 2. The objective of the upgrade is to eliminate the impact of Ayla and Saraya, thus bringing the network hydraulic conditions back to baseline demand system performance.

The 150 mm pipeline, on which the new demand junction will be located, should be converted to a supply line (main loop) in order to isolate the impact of the new load from the internal distribution zone. Accordingly, a parallel line 150 mm has been proposed as shown in Figure 5-8.

The low pressure nodes in the network are illustrated in Figure 5-9. As may be concluded from this figure, the new 150mm pipeline, approximately 2.3 km long has been able to isolate the influence of Ayla and Saraya from the existing network.

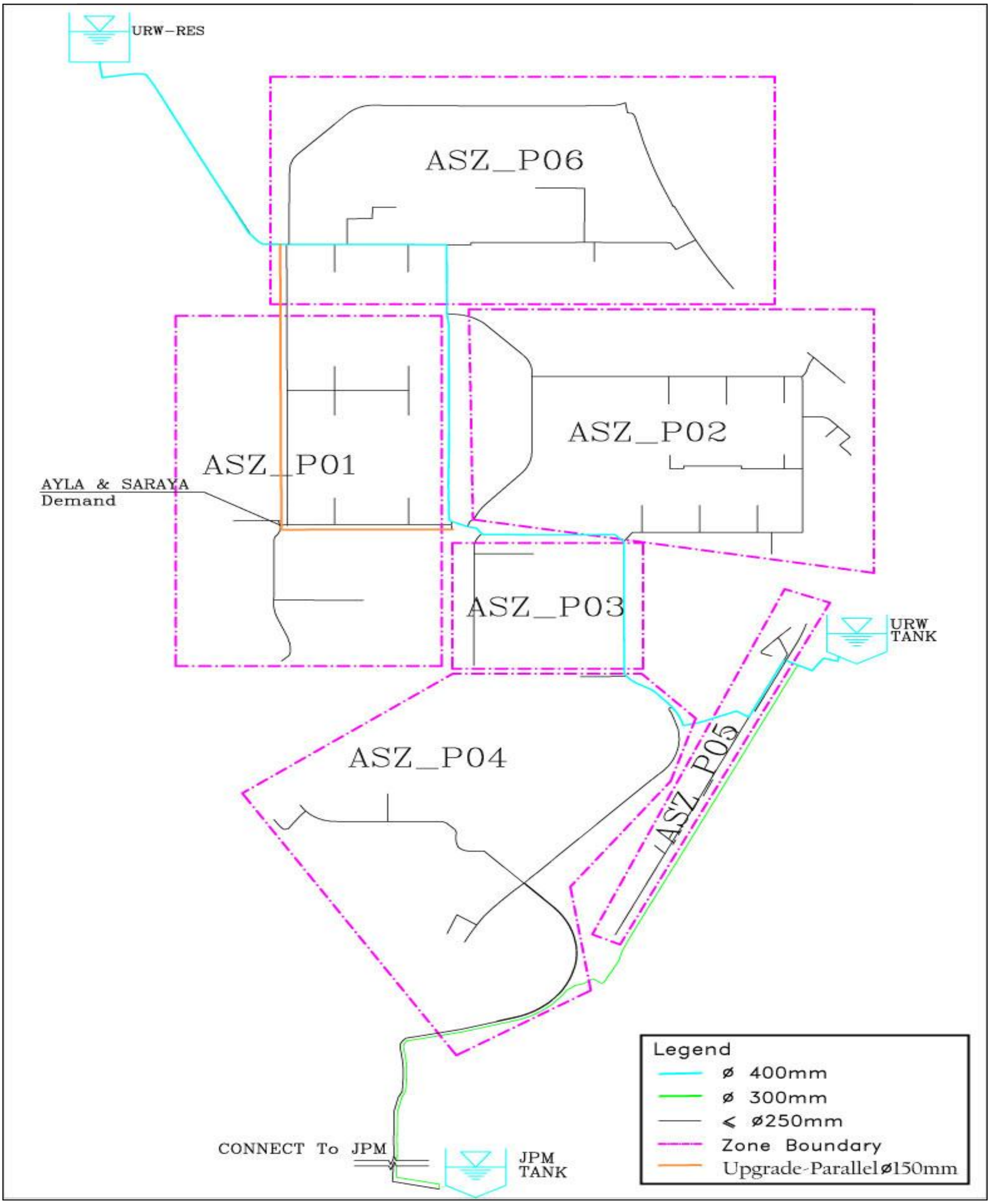

Figure 5-8: Future Scenario (2) - Upgrade schematic

Figure 5-9: Future Scenario (2) – Model results after Network Upgrade

Table 5-3 gives the ranges of pressures in Zone P01 under different model simulations. The three simulations compared in this table are:

- ASEZA demand and existing network
- ASEZA demand, plus Ayla and Saraya, with existing network
- ASEZA demand, plus those of Ayla and Saraya under the upgraded network (parallel lines).

Table 5-3: Range of pressures (m) in Zone ASZ-P01 (min. to max.)

Multiplier on ASEZA demand	ASEZA demand - existing network	ASEZA +Ayla+ Saraya demands - existing network	ASEZA +Ayla+ Saraya demands - upgraded network (parallel lines)
1.0	55 to 79	(-1.6) to 40	35 to 55

As may be concluded from the ranges of pressures in the table, the impact of the new developments on ASEZA's Zone P01 network is evident; the proposed improvement will be capable of isolating Ayla and Saraya, and in eliminating their impact on the hydraulic capacity of the existing city network.

5.4.4 Future Demand (Scenario 3) ASEZA 1.5 plus Ayla and Saraya

Significant increase in the number of negative and low pressure junctions can be noted in this scenario compared with Scenario 2. This increase is attributed to increase in head losses in the network pipes due to the increase in ASEZA demand compounded by the effect of Ayla and Saraya. Similar to Scenario 2, Zone P01 is the zone affected most by this scenario.

As in the case of Scenario 2, upgrade of the existing network will help improve the network performance under this scenario. In order to verify the network performance under system upgrade proposed above, namely, the parallel lines to the 150mm pipeline, a simulation run was carried out for the Scenario 3 demands with the upgraded network. The objective of the model run was to verify that the same upgrade would isolate the impact of Ayla and Saraya from the existing network, thus bringing the network hydraulic condition to that of Scenario 1.

The results of this simulation are presented in Figure 5-10 illustrating the low pressure junctions. As may be concluded from the figure, the parallel line of the 150 mm pipeline has been successful in transforming these distribution lines to a primary loop, then limiting the impact of the new demands on the existing network, particularly on zone P01.

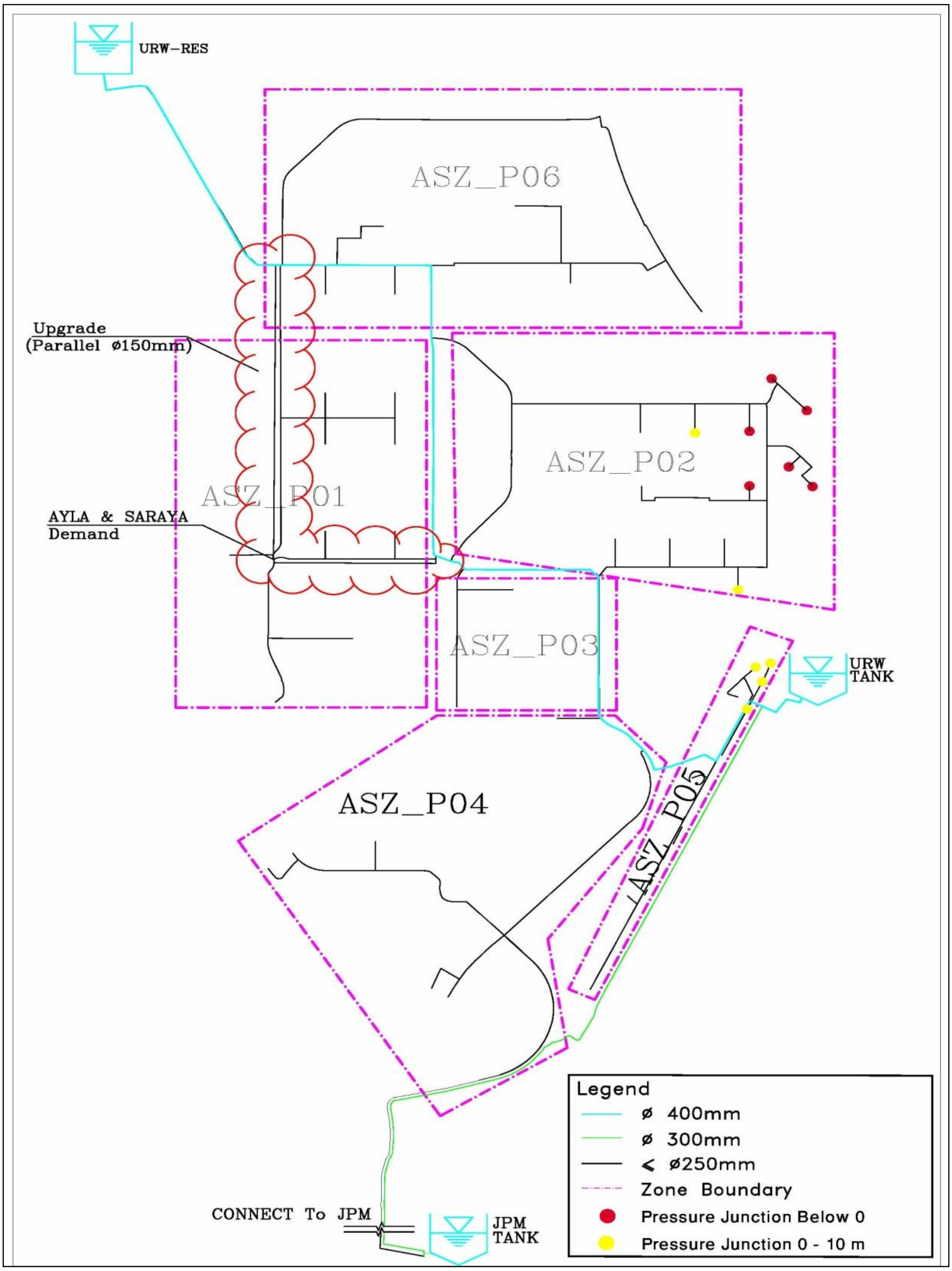

Figure 5-10: Future Scenario (3) - Model results after Network Upgrade

A comparison of the changes to the pressures in Zone 1 is, again, given in a tabular format, in Table 5-4

The table compares the results of the following conditions:

- the ASEZA 150 % demand under existing network

- the ASEZA 150 % demand, plus Ayla and Saraya, also under the existing network and
- the ASEZA 150 % demand, plus Ayla and Saraya, under the upgraded (parallel) network.

Table 5-4: Range of pressures (m) in Zone ASZ-P01 (min. to max.)

Multiplier on ASEZA demand	ASEZA demand - Existing network	ASEZA +Ayla+ Saraya demands - Existing network	ASEZA +Ayla+ Saraya demands - upgrading network (Parallel Lines)
1.5	46 to 74	(-14) to 36	24 to 48

As may be concluded from the table, the impact of the new developments on ASEZA's Zone 1 network is evident; the proposed improvement will be capable of isolating Ayla and Saraya and eliminating their impact on the hydraulic capacity of the existing URW network.

5.5 Future Demand of Marsa Zayed

The projected URW demand of Marsa Zayed could not be obtained from the developer. For the purpose of the network hydraulic modeling, the demand of this development was predicted as 70 percent of the total wastewater generated by the development at its full potable water demand of 6.95 MCM per year by the year 2030, equivalent to 130 L/s.

Currently, Ayla and Saraya developments are under construction. Hence, Future Scenario (2) evaluated and discussed earlier is the most credible scenario to take place in the near future. Accordingly, URW network was evaluated under predicted Marsa Zayed demands and Scenario (2) conditions, in addition to the following assumptions:

- Marsa Zayed will be supplied from the existing network by the 300 mm pipeline that feeds JPMC
- The Marsa Zayed projected high demand of URW is 130 L/s
- Marsa Zayed will be fully developed after Ayla and Saraya
- The recommended major upgrade works in Zone 1 will be completed before Ayla and Saraya are at full operation.
- The pumps at the URW reservoir should be upgraded to cover the additional flow of 130 L/s. That is, the upgraded pump should be able to deliver approximately 310 L/s.

The model was run under the above conditions and new pump configurations; new design flow of 310 L/s instead of 170 L/s and new design head of 120m instead of 105m. The results of this simulation indicate adequate pressures and velocities within the URW network.

Marsa Zayed is not expected to start operating at the high demand of 130 L/s before the year 2030. Hence, a sensitivity analysis was performed on "Scenario 2" upgraded network with several low demands of Marsa Zayed. It was observed that the upgraded system of Scenario 2 will be capable of supplying Marza Zayed continuously with URW up to a flow of 25 L/s without affecting the upgraded network performance.

5.6 South Service Area – JPMC and Tala Bay

As discussed in the previous chapter, the south service area covers the area between the existing port and the Saudi Borders. The port will be replaced in the near future by a new development, Marsa Zayed, which will form the divide between the North and South Service Areas. The URW consumers in the South Service area and their future supplies are discussed in the following paragraphs.

5.6.1 JPMC

Although JPMC is located in the South Service Area, its demand has been included in the North Service Area model. JPMC has a continuous demand and is supplied from the existing network by two supply pipelines Ø300 and Ø250 mm. Scenarios 1, 2 and 3 presented above assumed no increase in JPMC future demand.

5.6.2 Tala Bay

Tala Bay is already functional and has its own treatment plant with the following current conditions obtained from Tala Bay treatment plant engineers:

- Total capacity of the plant: 1300 m^3/day
- Wastewater flow into the plant: 500-600 m^3/day in low seasons and approximately 1000 m^3/day in high seasons
- There are two storage tanks near the treatment plant; they are used for storing reclaimed water during high seasons to be used in low seasons
- Approximately 5000 m^3/month is the total shortage of reclaimed water during the four summer months of June through September

The south service area model run simulated a scenario to serve Tala Bay from the existing URW network. The demand for Tala Bay was located on the 300 mm pipeline feeding the JPMC. The model results revealed that the network will maintain its current conditions in terms of velocities and pressures throughout the existing network. The results of this scenario were predictable due to the low URW demand of Tala Bay which is basically the shortage of 2 L/s.

Hence, Tala Bay could be served from the existing URW network since it would not impact the existing supply system.

5.7 Conclusions

Urban Reclaimed Water network simulations were presented in the above paragraphs under different demands and network conditions. The simulations represented present and future conditions as well as sensitivity analyses pertaining to uncertain future conditions.

As may be concluded from the above discussion of results, the existing network performance is satisfactory under the existing (year 2010) demands. Better management of the irrigation periods (diurnal pattern) over the six irrigation zones of ASEZA network will result in further improvement to the pressures in the network.

The sensitivity analysis on ASEZA demands revealed that if the additional ASEZA demands were to be allocated uniformly to the existing turnouts, Zone P02 would encounter problems of low pressures and high velocities. It is not recommended, however, that an upgrade to the network be carried out at this stage to address this problem because the future demand of ASEZA irrigation, in terms of quantities and distribution is uncertain and not accurately reflected in the model.

Under the conditions of Ayla and Saraya demands added to the present network, a major impact would be expected, especially in Zone P01. If their demands were to be supplied from the existing WWTP and existing network, a 150 mm parallel line approximately 2.3 km long would be required to reinforce the existing system with a new loop of main lines. This upgrade would eliminate the impact of the new demand on the internal distribution network.

High demand of Marsa Zayed can be accommodated in the existing network when the recommended upgrades of Zone P01 of the network and the pumps set at the WWTP and take place.

In general, it may be concluded that:

- Increase in ASEZA demand in current service area will primarily impact Zone P02. Other zones appear to have adequate capacities based on above mentioned demand assumptions.

- If Ayla and Saraya were to be connected to the network, upgrading of Zone P01 pipes would be needed.

- Upon completion of the Zone P01 upgrade, as recommended under Scenario 2, the network can accommodate up to 25 L/s of Marsa Zayed demand. Higher demands of Marsa Zayed will require upgrading the pumps set at the WWTP in order to deliver higher flows at higher pressure heads.

Table 5-5 summarizes the flow assumptions, model run results, and recommendations for each scenario discussed in this section:

Table 5-5: Summary of Hydraulic Modeling Scenarios:

Scenario	Flow Assumptions	Results	Solutions/Recommendations	Comments
ASEZA baseline demand (existing conditions)	- ASEZA : 30 l/s average daily demand; six supply zones, 3hrs/day for each zone - JPMC : 48.2 l/s continuous supply - A&S* : not connected - MZ&TB**: not connected	- Low pressure at some junctions in Zones 2 and 5, the latter zone being due to high ground levels mainly	- None since no reported problems with current operation.	- ASEZA demand was based on the actual consumption reported in the ETA 2010. - A low pressure taken to be <1.0 bar for all scenarios - Field verification of network pressures is recommended to confirm model results. - No change in URW current pumps settings
Future Scenario 1: ASEZA baseline demand X 1.5	- ASEZA: 45 l/s average daily demand; six supply zones, 3hrs/day for each zone - JPMC: 48.2 l/s continuous supply - A&S* : not connected - MZ&TB**: not connected	- Negative pressures + high velocities in Zone 2 - Low pressures in Zone 5 - Based on equal distribution of future demand among present turnouts, the remaining zones appear to have adequate capacities.	- Upgrade Zone 2 pipes (minor upgrade). However, before upgrading Zone 2, verify future demand, service areas, zoning and diurnal pattern.	- ASEZA forecast requirement 3.6MCM =113 l/s for 2030. Only 45 l/s of this is used for the simulation of the existing network. - Future service area of ASEZA is not known. - Same existing turnouts distribution, zones and diurnal distribution assumed. - Extra load of ASEZA was divided equally among existing turnouts - No change in URW current pumps settings
Future Scenario 2: ASEZA baseline demand + Ayla +Saraya	- ASEZA: 30 l/s average daily demand; six supply zones, 3hrs/day for each zone - JPMC: 48.2 l/s continuous supply - A&S*: 98.4 l/s continuous supply - MZ&TB**: not connected	- Negative pressures and high velocities in Zone 1 - Low pressures in Zones 2 and 5 with latter due to high ground levels.	- Major upgrade in Zone 1: 2.3km long 150mm parallel pipeline to existing 150mm pipeline.	- Ayla demand 63 l/s given by Developer - Saraya demand taken to be 34 l/s but not confirmed with developer. - Ayla and Saraya connected to network at Zone 1. - No change in URW current pumps settings

Scenario	Flow Assumptions	Results	Solutions/Recommendations	Comments
Future Scenario 3: ASEZA baselineX1.5 +Ayla+Saraya	- ASEZA: 45 l/s average daily demand; six supply zones, 3hrs/day for each zone - JPMC: 48.2 l/s continuous supply - A&S*: 98.4 l/s continuous supply - MZ&TB**: not connected	- Negative pressures and high velocities in Zones 1 and 2. - Low pressures in Zone 5 mainly due to high ground levels.	- Upgrade Zone 2 pipes (minor) - Major upgrade in Zone 1: 150mm pipeline 2.3 km long.	- Same comments as Scenarios 1 and 2. - No change in URW current pumps settings
Future Scenario of Marsa Zayed High demand: Marsa Zayed demand added to the upgraded network of Scenario 2	- ASEZA: 30 l/s average daily demand; six supply zones, 3hrs/day for each zone - JPMC: 48.2 l/s continuous supply - A&S*: 98 L/s continuous supply - MZ&TB**: 135 L/s continuous supply	- Low pressures in Zone 5 mainly due to high ground levels	- Upgrade of existing pump set at WWTP from 170 L/s flow & 105m head to a flow of 310 L/s and head of 120 m.	- Tala Bay is already functional and has its own treatment plant, yet they are in shortage of 5 L/s. - Marsa Zayed and Tala Bay were connected to Ø300 branching off main Ø400 pipeline feeding JPMC - URW pumps setting changed to 310 L/s design flow and 120 m design head.
Future Scenario of Marsa Zayed Low demand: Marsa Zayed demand added to the upgraded network of Scenario 2	- ASEZA: 30 l/s average daily demand; six supply zones, 3hrs/day for each zone - JPMC: 48.2 l/s continuous supply - A&S*: 98 L/s continuous supply - MZ : 25 L/s continuous supply	- Low pressures in Zone 5 mainly due to high ground levels	- No need for any modifications after the upgrade of Zone P01 of Scenario 2.	- Marsa Zayed was connected to Ø300 branching off main Ø400 pipeline feeding JPMC - No change in URW current pump settings

*: Ayla and Saraya
**: Marsa Zayed and Tala Bay

6.0 SUSTAINABLE AND COST EFFECTIVE MANAGEMENT PRACTICES

Integrated Water Resources Management is a systematic planning process that offers balanced consideration to supply and demand management planning alternatives at a reasonable cost to its users. It seeks to identify and manage risk and provides planning coordination between water and wastewater practices within a given planning area.

This chapter provides a review of the rules, policies, reuse agreements, management techniques and practices that form an integrated approach to sound water management.

6.1 Legal and Institutional Review

The legal and institutional tools consist of the rules and organizational arrangements for managing reclaimed water use and demand, including water rights, priority of use, role and authority of the water regulator, reclaimed water pricing, the protection of reclaimed water quantity and quality, and licensing. These tools should be complemented by mechanisms to encourage coordination between various water agencies and enforcement bodies.

The Kingdom of Jordan, through its Ministry of Water, has adopted a strategy that places high value on water reclamation; “Wastewater shall not be managed as waste; it shall be collected and treated to standards that allow its use in unrestricted agriculture and other non-domestic purposes, including ground water recharge”.

As per articles No. 9 and 11 of the environment protection law No.1 of the year 2003 and as per ASEZA zero discharge policy to the Gulf of Aqaba, any wastewater produced within the ASEZ should be treated to meet standards for reuse. Jordanian Standard (JS) 893/2006, addressing Water-Reclaimed Domestic Wastewater and issued by the Jordan Organization for Standards and Metrology specifies the conditions that the reclaimed domestic wastewater discharged from wastewater treatment plants should meet in order to be discharged or used for non-domestic purposes. JS 389/2006 specifies:

- The level of wastewater treatment required for specified uses
- Treatment reliability requirements
- Limits for water quality parameters
- Site access restrictions
- Management practices

Section 6-2-2 of the standard provides the treatment levels in terms of specific water quality parameters. Table 3 (of the Standard) presents water quality parameters that may not be exceeded for the designated uses and Table 4 presents guidelines for other water quality parameters that, if exceeded, must be studied to determine the scientific effects on public health and the environment.

Other limitations on the use of reclaimed water that are specified in the Standard are:

- It is prohibited to use reclaimed water for irrigating vegetables that are eaten uncooked (raw).
- It is prohibited to use sprinkler irrigation except for irrigating golf courses and in that case irrigation should be practiced at night and the sprinklers must be of the movable type and not accessible for day use.
- When using reclaimed water for irrigating fruit trees, irrigation must be stopped two weeks prior to fruits harvesting and any falling fruits in contact with the soil must be removed.

Aqaba's URW and ARW systems comply with these regulations. URW is fully utilized by three customers; Jordanian Phosphate Mining Company for industrial purposes including cooling water and landscaping, the King Hussein International Airport for agriculture, and ASEZA for landscaping and agriculture.

6.2 Water Quality Monitoring and Evaluation

The USAID RIAL I pilot projects demonstrated that wastewater reuse requires monitoring. On more than one occasion, the reclaimed water received at pilot sites did not meet Jordanian Standards.

The Aqaba Water Company is responsible for testing and compliance with JS 893/2006. The Ministry of Water and Irrigation through the Water Authority of Jordan and the Jordan Valley Authority (JVA) confirms compliance through monthly site visits, audits of AWC records, and collection/analysis of independent water quality samples.

Aqaba'a WWTP produces wastewater effluent that exceeds the Standard for Category B Reclaimed Water for almost all of the tested parameters (See Table 6-1):

Table 6-1: Comparison of Effluent Parameters vs. Standard

Parameter	JS 893/2006 Standard	AQABA Mechanical WWTP*
Biochemical Oxygen Demand	200 mg/L	5.2 mg/L
Chemical Oxygen	500 mg/L	17 mg/L
Dissolved Oxygen	n/a	0.5 mg/L
Total Suspended Solids	200 mg/L	4.5 mg/L
pH	6 – 9 units	7.2
Nitrate	45 mg/L	29 mg/L
Total Nitrogen	70 mg/L	16 mg/L
E. Coli	1000 mpn/100 ml	Not seen
Intestinal Helminthes Eggs	< or = to 1	Not seen
Fats, Oils, and Grease	8 mg/l	Not measured

*** 2010 Average Monthly Values**

6.3 Current Allocations

In 2010, the wastewater treatment plant produced approximately 5.27 MCM of reclaimed water from a wastewater influent flow of 7.10 MCM. Of the 5.27 MCM of total reclaimed water, 2.81 MCM was classified as URW from the tertiary wastewater treatment facilities and 2.46 MCM was ARW from the natural wastewater treatment plant. In 2006, the Reuse for Industry, Agriculture and Landscaping (RIAL) Project – Task 1 Report stated that the Annual Water Reuse Factor for Aqaba was 60 % (based on reclaiming 3,188 m^3 [1.16 MCM] of water from 5,280 m^3 [1.93 MCM] of influent wastewater). This Reuse Factor has now increased to 74 % in 2010. See Table 6-2,

Table 6-2: Water Reuse Factor

	2006	2010
Total WWTP Effluent	1.93 MCM	7.10 MCM
Total Reclaimed	1.16 MCM	5.27 MCM
Annual Water Reuse Factor	60 %	74 %

WAJ has established a Water Reuse and Environment Unit (WREU) which is tasked with planning, monitoring and managing wastewater reuse projects and activities throughout Jordan. The WREU is also responsible for negotiating and executing agreements with farmers, industry, and commercial business owners for the reuse of treated wastewater.

Current reclaimed water allocations have been negotiated with the Jordan Phosphate Mines Company (JPMC), ASEZA, and the King Hussein Airport. These are summarized in Table 6-3:

Table 6-3: Current Reclaimed Water Allocations

	Reclaimed Water Rates	Reclaimed water limits by Contract	Approximate 2010 Flow (m^3)
JPMC	URW - 0.70 JD / m^3	1.5 million m3/year minimum; 2.0 million m3/year maximum	1,520,000
ASEZA	URW - 0.10 JD/m^3	2,500 m3/day maximum	730,000
	ARW - 0.03 JD/m^3	No limit	2,370,000
King Hussein Airport	ARW - 0.25 JD/m^3	2,500 m3/month minimum	30,000

All reclaimed water was used in 2010. The URW was used by JPMC and ASEZA (total of 2.24 MCM), and by AWC for landscaping and utility water uses at the wastewater treatment plant (0.6 MCM). Any unused URW was transferred to the ARW system for use by the farms and wildlife ponds. The ARW users pay a lower tariff for the reclaimed water use, so it would benefit AWC if they could identify additional commercial or industrial URW users to minimize the transferred URW.

The financial feasibility of reclaimed water often depends on the price of reclaimed water attainable under the existing economic conditions. It is a political decision whether charges for reclaimed water are set at a level to cover operation and maintenance costs or at a higher level to recover capital costs as well. In order to promote conservation of freshwater resources and to promote water reuse, it may be necessary to set the price for reclaimed water below the price that would have enabled full cost recovery. In any case, reclaimed water should be available at lower prices than the (sometimes subsidized) fresh water.

Aqaba has negotiated agreements with each of their reclaimed water clients. The tariff charged under each agreement is negotiated for the term of the agreement. Generally the agreements run from one to five years.

6.4 Future Allocations

As development occurs, the need for additional volumes of URW will increase. ASEZA has identified the following Projects that will create a demand for more reclaimed water (See Table 6-4):

Table 6-4: Future Reclaimed Water Allocations

Development Name	Reclaimed Water Rates
Ayla	URW – 5,000 m^3/day
Saraya	URW – 3,000 m^3/day
Marsa Zayed	URW – 3,080 m^3/day
Tala Bay	URW – to be determined

In order to supply this additional URW, it will be necessary to collect more wastewater or treat the existing ARW to URW standards. If these three developments collectively generate at least an additional 11,080 m3/day URW demand, the mechanical treatment plant must see an additional 12,590 m3/day influent wastewater flow in order to meet the demand.

6.5 Education, Communication, Public Awareness, and Participation

Institutional support is being provided to the Aqaba Special Economic Zone Authority to establish the “Water Resources Management Directorate” (WRMD) including a wastewater resources division to ensure the regulation and management of reuse activities in a sustainable and comprehensive fashion. In addition to this, a “Water Reuse Information Office” was established to form the base for a comprehensive communication and public awareness program. This awareness program aims to introduce clear and specific messages to Aqaba's community concerning water reuse as well as working proactively to manage misconceptions that could slow the migration to water reuse.

6.6 Demand Management

Water conservation is the most cost effective demand management strategy. It produces immediate results at the lowest possible cost. Water managers often say that the cheapest liter of water is one that is not used. Conservation is an essential tool in developing a long-term sustainable water supply and comes in many forms. The demand management practices currently in use in Aqaba are described below.

6.6.1 Public Outreach

Public outreach and education, including school curricula, are essential components in water reuse programs. Transparency, information sharing and involvement of water users and re-users and local community groups in the decision making process will also foster greater acceptance of water reuse. In agriculture, farmers should be educated on safe irrigation and post-harvest practices, and consumers need to be informed about the safety of agricultural products irrigated with well-managed reclaimed water. Water quality data must be widely available and freely shared with customers for the water and the general public. Stakeholder participation must be encouraged. Community groups need to be able to express their needs and suggestions in open multi-stakeholder platforms. Water conservation publications and promotional materials should be widely distributed.

AWC acknowledges the importance of public outreach by sponsoring “water awareness” activities in the community and by providing educational materials on its web site.

6.6.2 Non-Revenue Water

Non-revenue water (NRW) is water that has been produced and then lost before it reaches the customer. Such losses may be caused through leaking pipes, illegal connections, unbilled consumption, or metering inaccuracies. The imperative to effectively manage NRW is further heightened due to a rapidly growing population and the impacts of an arid climate which together put greater demand on scarce water resources. Implement a leak detection program utilizing surveillance techniques, certification and calibration of water meters to reduce water losses.

This problem is prevalent throughout Jordan. Solutions need to be tailored to local circumstances due to variation in the cause of water loss and the mechanisms available to manage them. In some cases, a greater proportion of water loss is of a commercial nature (customer meter under registration, data-handling errors, theft of water etc) in comparison to physical losses. On the solution side, the right mix of technological, institutional and financial mechanisms need to be adapted to meet local circumstances.

By simply improving efficiencies and maintenance of irrigation systems and working to educate customers in landscaping practices, such as plant selection and the frequency of watering, significant water savings can be realized.

Aqaba is aggressively addressing NRW reduction. Current water losses are estimated at 22 % to 23 % of production, which are lower than Jordan’s national average. AWC’s goal is to cut these losses in half in the next ten years.

6.7 Supply Management

6.7.1 Groundwater

The sole source of water supply for Aqaba City and the Aqaba Special Economic Zone is the Qa Disi well field. This groundwater source does not recharge and, therefore, is not sustainable in the long term. As a water supply option for Aqaba, further allocation of water from Disi is only viable as a short-term solution.

As Aqaba’s only source of water supply, Disi’s water quality should be protected against contamination from agricultural and industrial sources. MWI is currently working to develop water resources protection guidelines that will establish Groundwater Water Protection Zones in Jordan. Although the well fields lie outside of ASEZA's boundaries, ASEZA should become an advocate for implementing best management land use practices by petitioning MWI to include Disi in their protection program.

Another short-term solution to address immediate potable water demand shortfalls could be the re-commissioning of a local well field in Aqaba that was abandoned when Qa Disi came on-line. This source would need to be evaluated for water quality suitability, but may offer some cost effective short-term relief.

6.7.2 Desalinated Seawater

Other long-term water supply initiatives that have been discussed are:

- Jordan Red – Dead Sea Project
- Sahara Forest Project
- Aqaba 5 MCM Desalination Water Treatment Plant

Given the current global economic climate, it is unlikely that the Jordan Red – Dead Sea Project will likely move forward in the near term. The cost and scope of this project is staggering and will be delayed for many years.

In January, 2011, Jordan's government signed an agreement with a Norwegian group, the Sahara Forest Project, to explore the feasibility of condensing seawater in large greenhouses near the Red Sea. This could provide fresh water for irrigation and drinking. The program would include constructing a 20 hectare demonstration project near Aqaba and is expected to begin operations in 2015 (Science 2011).

A local, seawater desalination facility that can be expanded to provide increased volumes of water as the economy expands is the more cost effective water supply alternative. The AWC Aqaba Water Master Plan Report, September, 2009, introduces and describes this project.

6.7.3 Rainwater Harvesting

According to ASEZA, Aqaba does not currently harvest rainwater. Because of the arid climate, precipitation events normally occur only between the months of October and April and while they may be intense, they are always brief in duration. Annual average rainfall is typically 32 mm (WMO website) and may occur within a few days. Stormwater harvesting during these brief events would likely require solids removal due to the high sediment load associated with intense, short duration rainfalls.

Rainfall catchment systems are typically only effective in areas with an average annual rainfall greater than 200 mm per year (Skinner and Cotton, 1992). Given the likely poor yield from rainwater harvesting in Aqaba, this demand management tool is not recommended.

6.7.4 Stormwater Aquifer Recharge

Aqaba is subject to occasional flash flooding from severe storms occurring in the mountains outside of the City. Stormwater collects in wadis and is transported through the City to the Gulf of Aqaba. In 2006, a flash flood in Wadi Al Yutum resulted in fatalities and caused extensive infrastructure damage.

ASEZA has commissioned a study to address "Improved Drainage and Flood Control for the Aqaba Special Economic Zone Authority; Final Flood Protection Master Plan for Wadi Yutum and Adjacent Coastal Wadis." An initial draft of the report published in December, 2011 discussed the possibility of constructing a series of dams to reduce the peak flow velocity of stormwater as it passes through the Wadi. The report also identifies a secondary benefit of the dams in that retention of the flood waters would promote recharge of the surficial groundwater aquifer through infiltration. The report indicates that this captured rainwater could offer as much as 400,000 cubic meters of additional water per year to the aquifer.

If it is determined that the construction of the dams provides the necessary flood protection for Aqaba, ASEZA should evaluate the cost effectiveness of developing the infrastructure necessary to mine this recharged groundwater.

7.0 RECOMMENDATIONS

The findings and recommendations presented below are based on the analysis and evaluations performed in this study coupled with the work completed in previous water resources reports. This report focuses on updating previous demand projections to acknowledge the economic turndown that has occurred worldwide since 2008, and to use those new projections to guide future action plans.

7.1 Summary of Findings

Aqaba's water supply is provided by the non-sustainable Qa Disi groundwater aquifer. Further, according to the World Meteorological Organization, the average annual rainfall in Aqaba is only 32 mm (1.25 inches). This lack of rainfall combined with a lack of a reliable long term water supply make it difficult to manage their scarce water resources. Therefore, it is imperative that Aqaba maximizes its use of reclaimed water.

ASEZA and AWC have made significant progress over the last ten years in making reclaimed water widely available, cost effective, and safe to use in Aqaba. The recommendations that follow are intended to support that progress.

7.2 Recommendations

7.2.1 Water Supply and Policy

- Aqaba's potable water supply, the Qa Disi Aquifer, is finite and will, in time, be exhausted. ASEZA and AWC should take a long-term perspective by reducing their dependence on this groundwater source by planning for and developing desalination facilities.

- As a policy, Qa Disi water should not be used for landscaping. The process should begin to fund future desalination facilities by creating a water tariff to be levied on users who are using potable water for landscaping such as hotels, businesses, and large developments.

- Support innovative, sustainable programs that could substantially supplement Aqaba's water supply. The Sahara Forest Project has the potential to provide 9,000 m^3/day of water if a large scale facility is feasible.

7.2.2 Water Pricing

Jordan's Water Utility Policy (MWI, 1997) is to move toward full cost recovery and to use water tariffs to promote cost recovery considering water quality, end users as well as economic impacts on the various economic sectors.

- The current price for potable water (PW) is too low. The differential in the cost of PW versus reclaimed water is not substantial enough to justify the cost of additional infrastructure to utilize URW for landscaping. The highest projected growth rates will occur in the touristic and commercial sectors. These two sectors should shoulder the majority of the additional cost of water. It is important to address this water pricing issue before developers re-start their projects so that the economics benefiting the use of URW are considered.

- Users who are not connected to the sewer system and who do not reclaim their own wastewater for reuse should pay a higher price for PW.

- As a strategy for meeting future water needs, ASEZA should support developments that integrate water reuse and conservation practices.

7.2.3 Reclaimed Water

The existing reclaimed water storage and collection systems are adequate for current demands. As development occurs and demands increase, the current infrastructure in Zone PO1 will require reinforcement. If ASEZA increases their use of URW for landscaping throughout the City, pressures and flows will decrease in Zone PO2.

- Reclaimed water storage capacity will soon be 130,000 m^3. At current ARW + URW demand levels, this provides approximately nine days of storage. Based on 2030 reclaimed water demand projections, 130,000 m^3 will provide just over two days of storage. Alternatively, it provides thirty days of storage of JPMC's current level of URW usage (4,161 m^3/day) assuming that the storage begins empty and that all other reclaimed water demands remain constant. AWC and ASEZA should develop a reclaimed water storage management program to prevent reclaimed water from accumulating in storage, which could result in violating ASEZA's zero discharge policy.

- When the economy turns around, developers will re-start projects and look for landscaping water first without providing a wastewater discharge. Aqaba should be ready to provide URW by reinforcing and expanding their existing reclaimed water infrastructure. This may involve making the capital investment decision in advance of the increased demand.

- AWC should begin the planning necessary to divert larger percentages of influent wastewater from the natural treatment plant to the mechanical treatment plant. This will allow larger quantities of URW to become available to support development and industrial expansion.

- Greening the City should be a priority. ASEZA should have continued access to URW.

- Developers should be encouraged, financially, to plant “low water use” landscaping.

REFERENCES

Aqaba Development Corporation, www.adc.jo.

Aqaba Special Economic Zone, www.aqabazone.com.

Aqaba Water Company website, http://aqabawater.com.

Aqaba Water Company. June 2011. Reclaimed Water Demand and Tariff.

CDM. December, 2011. Draft Report. Improved Drainage and Flood Control for the Aqaba Special Economic Zone Authority. Final Flood Protection Master Plan for Wadi Yutum and Adjacent Coastal Wadis.

Changi Airport Consultants. August 2008. King Hussein International Airport Aqaba Final Master Plan Report for Aqaba Development Corporation.

ECODIT/PA Government Services, Inc. January 2004. Aqaba Pilot Water Study Water Reuse Report: Allocation Needs and Options for USAID.

Engicon. 2009. Aqaba Master Plan Report for Aqaba Water Company. September 2009.

Engicon. 2008. Master Plan for Upper Town Project in Aqaba.

ICON Architecture, Inc. in association with Consolidated Consultants, Inc. May 2007. Master Plan for North and South Villages for Aqaba Development Corporation.

MWH. 2010. Aqaba Wastewater Collection System Master Plan.

Ministry of Water and Irrigation. 1997. Jordan's Water Utility Policy.

PA Consulting Group. 2004. Aqaba Water Reuse Report: Allocation Needs *and Options.*

Royal Haskoning. April 2006. Aqaba Industrial Zone & South Port Projects, South Zone Master Plan for Aqaba Development Corporation.

Science Magazine, Volume 331, January 14, 2011)

Share', Hussein al, Ayla. July 27 2011. Email conversation.

Sigma Consulting Engineers. August 2008. Aqaba South Coast Waste Water System for Aqaba Water Company and Aqaba Development Company.

Cotton, A.P. and Skinner, B.H. 1992. Community Rainwater Catchment, 108 pp, International Labour Office

Waller, Dr. Peter and Eng. Hanadi Amr. February 2005. Aqaba Reclaimed Water Requirements for Landscaped Areas.

World Meteorological Organization website, http://worldweather.wmo.int/069/m069.htm

USAID. 2005. Reuse for Industry, Agriculture and Landscaping (RIAL) Project (2005), ASEZA Water Resources Management Division: Institutional Development Plan.

USAID. 2006. Reuse for Industry, Agriculture and Landscaping (RIAL) Project (2006), Aqaba Special Economic Zone Authority (ASEZA) Water Reuse Information Office Design Report.

USAID. 2004. Technical Support for Procurement, Project Management, and Private Sector Participation.

USAID. December 2005. Water Reuse in Aqaba Special Economic Zone: Communication Strategy and Workplan

USEPA. September, 2004. Guidelines for Water Reuse.